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PHOTOVOLTAIC ENERGY SYSTEMS

ORIGINAL

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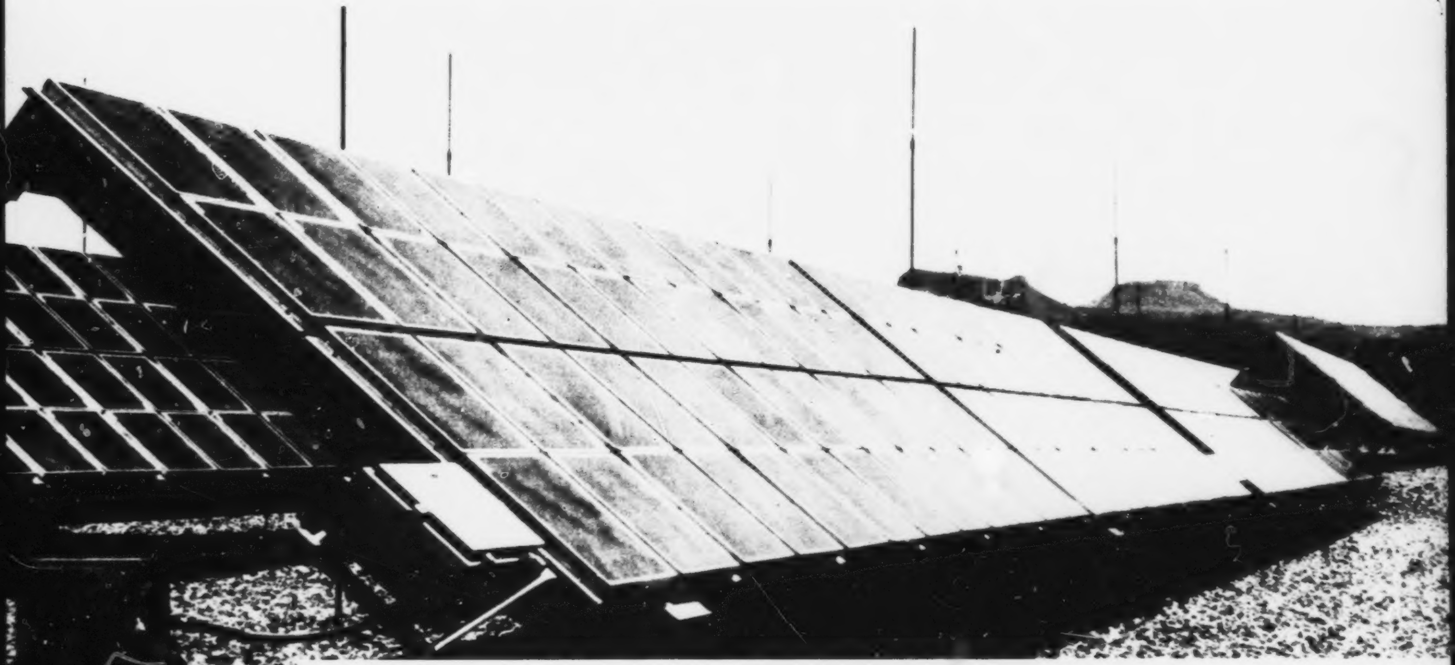
475

Program Summary

January 1981



U.S. Department of Energy
Assistant Secretary for Conservation
and Renewable Energy

Front Cover

NATURAL BRIDGES NATIONAL MONUMENT, UTAH. The 100-kW peak photovoltaic power system at the Natural Bridges National Monument, Utah. The photovoltaic array contains twelve 200-foot rows. Eight 8 x 24-foot frames are used to support the solar cells in each row. Mounted behind the frames are lightning rods which provide protection against direct lightning strikes. In the background, the twin peaks of Bears Ears silently punctuate the eastern horizon.

JOHN F. LONG HOMES, INC. PHOENIX, ARIZONA. Site of the first demonstration of an architecturally integrated solar electric roof. Manufactured by ARCO Solar, Inc., the solar system incorporates photovoltaic cells onto standard batten and seam roofing material. It produces approximately 6 kW per peak hour of 11,000 to 13,000 kW-h per year. The demonstration is located on a model home built by John F. Long Homes, Inc.

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PHOTOVOLTAIC ENERGY SYSTEMS

Program Summary

January 1981

U.S. Department of Energy
Assistant Secretary for Conservation and
Renewable Energy
Washington, D.C. 20585

II

PREFACE

The National Photovoltaics Program was initiated to provide focus, direction, and funds for the development of solar photovoltaic power. Its objective is to develop cost-competitive photovoltaic energy systems capable of supplying a significant portion of the nation's energy requirements.

Each year a program summary is prepared which provides an overview of government-sponsored activities within the Photovoltaics Program. This summary highlights the ongoing research, development, and demonstration efforts and describes each of the U.S. Department of Energy's (DOE) current photovoltaics projects initiated or renewed during fiscal year 1980 (October 1, 1979, through September 30, 1980).

The FY 1980 Photovoltaic Energy Systems Program Summary is a follow-up to the FY 1979 Program Summary, DOE/CS-0146, published in January 1980, and available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

ABBREVIATIONS AND ACRONYMS

AR&D	Advanced Research and Development
Btu	British thermal unit
CR	commercial readiness
CTD	concentrator technology development
EFG	edge-defined film-fed growth (silicon ribbon process)
EFT	engineering field test
EPR	ethylene-propylene-rubber (encapsulant for terrestrial modules)
EPSDU	Experimental Process System Development Unit
EVA	ethylene vinyl acetate (encapsulant for terrestrial modules)
FPUP	Federal Photovoltaic Utilization Program
FY	Fiscal year
GaAs	Gallium arsenide
ISEE	initial system evaluation experiment
JPL	Jet Propulsion Laboratory
kg	kilogram
kW_p	kilowatt peak (or the amount of electrical energy generated by a solar system at peak daytime exposure to the sun)
LSA	Low-Cost Solar Array
MEPSDU	Module Experimental Process System Development Unit
MIT/EL	Massachusetts Institute of Technology/Energy Laboratory
MIT/LL	Massachusetts Institute of Technology/Lincoln Laboratory
MW	megawatt
NASA	National Aeronautics and Space Administration
NASA/LeRC	National Aeronautics and Space Administration/Lewis Research Center
NOAA	National Oceanic and Atmospheric Administration
NWC	Naval Weapons Center
PA&I	Planning, Analysis, and Integration
PDU	product development unit
PRDA	Program Research and Development Announcement
PURPA	Public Utility Regulatory Policies Act
PV	photovoltaic or photovoltaics
PV/T	photovoltaic/thermal
Quad	10^{15} Btu
RD&D	Research, Development, and Demonstration
RFP	Request for Proposal
SD	Systems Development
SEMIX	A direct sheet growth technique using polycrystalline sheet material
SERI	Solar Energy Research Institute
SF	system feasibility

ABBREVIATIONS AND ACRONYMS (Cont'd)

SR	system readiness
SSRL	Severe Storms Research Laboratory
Sandia	Sandia National Laboratories
Soleras	Project agreement for cooperation in the field of solar energy between the United States and Saudi Arabia
T&A	Tests and Applications/Industry Assistance
TF	technical feasibility
TR	technical readiness

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PART ONE
PROGRAM SUMMARY

SECTION I

INTRODUCTION

The conversion of solar power by photovoltaics (PV) has long been recognized as a potentially abundant source of clean, renewable electrical power. Photovoltaic systems require no complex machinery or moving parts; they are basically modular, and therefore adaptable and potentially cost-effective in large as well as small-scale applications.

Photovoltaic solar cells are solid-state devices that instantly and silently convert direct sunlight into electricity. Individual solar cells are interconnected and encapsulated to form a PV module. Groups of modules are then interconnected to form a PV array. The complete PV generating system includes the array plus power conditioning equipment, wiring, and the necessary auxiliary devices.

The technical feasibility of photovoltaics has been a demonstrated fact for many years, and PV technology for specialized uses is relatively advanced. For example, PV solar cells have been used extensively to provide power for space satellites. However, the relatively high cost of systems being produced confined any broader scale applicability to small-scale, remote operations. For photovoltaics to augment the national electrical energy needs significantly, electricity must be produced at costs reasonably competitive with electricity from other conventional generating sources.

SECTION II

THE NATIONAL PHOTOVOLTAICS PROGRAM

A. HISTORY

In the early 1970's, with a forecast of impending worldwide shortages of nonrenewable energy sources and the nation's increasing dependence upon imported fossil fuels, national emphasis was directed toward the development of alternate energy resources for terrestrial applications as a reliable alternative.

In 1972 in response to this challenge, the National Photovoltaics Program was initiated to implement wide-ranging research and development tasks and to provide coordination for the efforts of government, private industry, universities, and laboratories. Under the sponsorship of the National Science Foundation, the established objective was to bring photovoltaic energy systems costs to the point where they would be able to supply a significant portion of the nation's energy requirements – to accelerate the development of reliable and economically viable energy systems while working to stimulate their earliest possible competitive market penetration and widespread use.

On October 24, 1974, the Solar Energy Research, Development, and Demonstration Act (Public Law 93-473) was signed into law by Congress. Its goal was to provide the nation with the option of using solar energy as an alternative source for meeting future terrestrial energy requirements.

From 1975 to 1977, the Division of Solar Energy of the Energy Research and Development Administration (ERDA) led the effort in photovoltaics technology development, systems development, and demonstration. In October 1977, the Photovoltaics Program was assumed by the U.S. Department of Energy (DOE) through the Department of Energy Organization Act (Public Law 91-565).

During 1978, an important series of energy-related bills was enacted into law which served to further define and augment the thrust of the Photovoltaics Program. On February 25, 1978, the Department of Energy Act (Public Law 95-238) was passed. This law authorized $19 million for photovoltaics. Specifically, $6 million was for automation studies using life-cycle costing techniques; $13 million was to "initiate and conduct an 'application and system design study,' cooperatively with appropriate Federal agencies, to determine the potential for the use of solar photovoltaic systems at specific Federal installations". The first series of bids was solicited in fall 1978.

That program was greatly augmented when, on November 9, 1978, the National Energy Conservation Policy Act (Public Law 95-619) was passed, formally establishing the Federal Photovoltaic Utilization Program (FPUP), and authorizing an additional $98 million to FPUP for fiscal years 1979-1981.

On November 4, 1978, Congress passed the Solar Photovoltaic Energy Research, Development, and Demonstration Act (Public Law 95-590). This law mandated a 10-year, $1.5 billion program of accelerated "research, development, and demonstration of solar photovoltaic energy technologies leading to early competitive commercial applicability of such technologies..." with the long-term objective of producing "electricity from photovoltaic systems cost-competitive with utility-generated electricity from conventional sources," and to resolve the social, technical, environmental, institutional, and legal issues involved in widespread adoption of photovoltaic power systems.

On November 9, 1978, Public Law 95-617, the Public Utility Regulatory Policies Act of 1978 (PURPA) was passed, mandating purchase of electricity from privately owned electricity generators by utilities at economically neutral rates.

This Annual Program Summary Report describes the current Photovoltaics Program, its active contracts, and the advances made during FY 1980 toward the achievement of its goals.

B. PROGRAM ORGANIZATION

The Photovoltaic Energy System Division is part of the DOE's Office of Solar Applications for Buildings, one of five administrative offices of the Deputy Assistant Secretary for Solar. This responsibility resides within the DOE Office of the Assistant Secretary for Conservation and Solar Energy. An overview of this organizational structure is shown in Figure 2-1.

The Photovoltaics Program is managed by the Photovoltaic Energy Systems Division. It is here that overall Program policy and budgets are developed, and plans and strategy approved. The actual day-to-day administration of the Program elements, however, has been decentralized and is shared by two designated Lead Centers. The Solar Energy Research Institute (SERI), located in Golden, Colorado, is Lead Center for Photovoltaics Advanced Research and Development (AR&D). NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, is Lead Center for Photovoltaics Technology Development and Applications (TD&A). These two Centers manage the detail planning, assessment, and implementation of the Program to meet the guidelines and objectives established by the DOE Program Office, including the coordination of involved Field Center organizations and activities. The TD&A Lead Center is also responsible for management of the FPUP activities. This structure is outlined in Figure 2-2. Both Lead Centers also serve to further promote the development and advancement of photovoltaics within the commercial industry and private sector.

C. SUBPROGRAM ELEMENTS

Implementation of the Photovoltaics Program is carried out within four major technical subprogram elements, designed to promote the research, development, and demonstration of proven concepts in a timely and systematic manner:

(1) Advanced Research and Development (AR&D).

(2) Collector Technology Development (CTD).

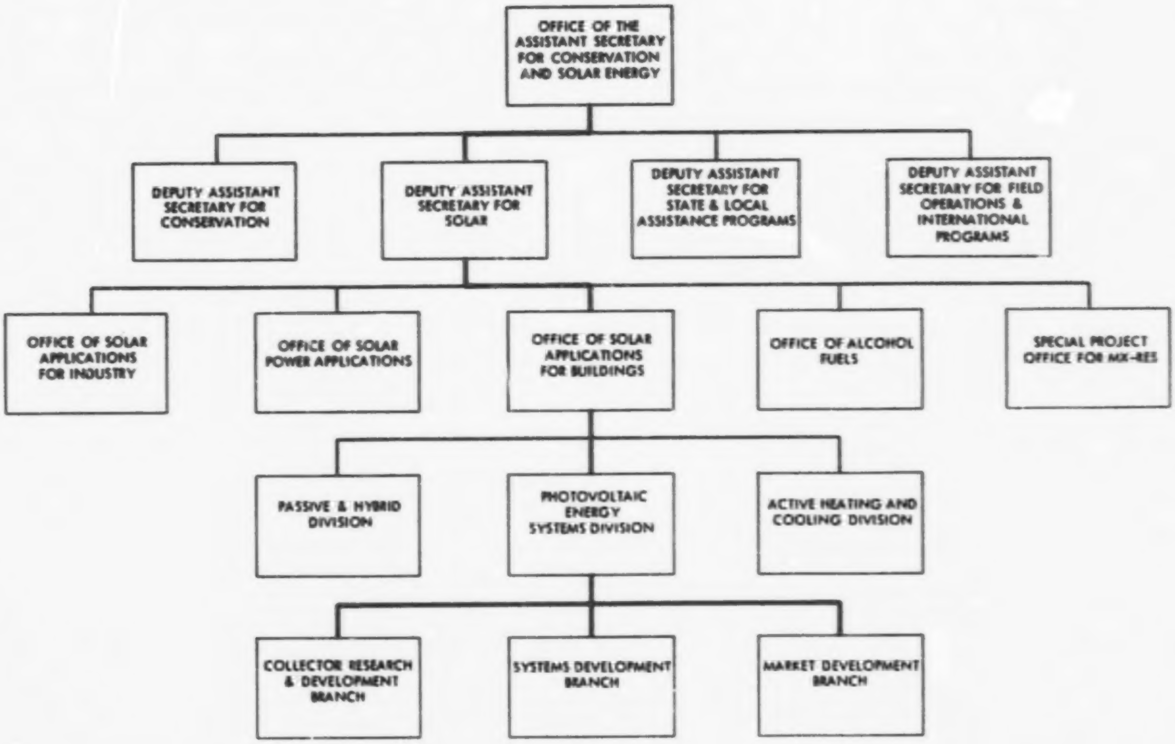
(3) Systems Development (SD).

(4) Tests and Applications/Industry Assistance (T&A).

A fifth element, that of Planning, Assessment, and Integration (PA&I), provides the named functions as well as mission, economic, and policy analysis for the Photovoltaics Program as a whole. The PA&I element provides the focus for monitoring major milestones and leading assessments of Program progress and funding options analysis through the coordinated effort of each subprogram.

1. Current Program Approach

The approach taken in conducting the Program relies upon early and intensive effort to reduce costs of all elements of the system, its installation and operation. Initial investigation of promising materials and device concepts is carried out within the Advanced Research and Development Subprogram element. Once a concept demonstrates "technical feasibility" (TF), that is, the potential for meeting certain established cost and performance standards, it advances to the Collector Technology Development (CTD) stage where it is subjected to intensive design, performance, and production technology development efforts. The objective is to achieve cost/performance goals which will lower the costs of systems employing these advanced collectors. Successful conclusion of the CTD stage results in demonstration of "technology readiness" (TR); i.e., the ability to show how the collector can be manufactured at or below the price goals. Promising collectors and other system components are employed in Systems Development activities where prototype systems are developed and tested.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DEPUTY ASSISTANT SECRETARY FOR CONSERVATION
DEPUTY ASSISTANT SECRETARY FOR SOLAR
DEPUTY ASSISTANT SECRETARY FOR STATE & LOCAL ASSISTANCE PROGRAMS
DEPUTY ASSISTANT SECRETARY FOR FIELD OPERATIONS & INTERNATIONAL PROGRAMS
OFFICE OF SOLAR APPLICATIONS FOR INDUSTRY
OFFICE OF SOLAR POWER APPLICATIONS
OFFICE OF SOLAR APPLICATIONS FOR BUILDINGS
OFFICE OF ALCOHOL FUELS
SPECIAL PROJECT OFFICE FOR MX-RES
PASSIVE & HYBRID DIVISION
PHOTOVOLTAIC ENERGY SYSTEMS DIVISION
ACTIVE HEATING AND COOLING DIVISION
COLLECTOR RESEARCH & DEVELOPMENT BRANCH
SYSTEMS DEVELOPMENT BRANCH
MARKET DEVELOPMENT BRANCH

Figure 2-1. Solar Energy Management Organization

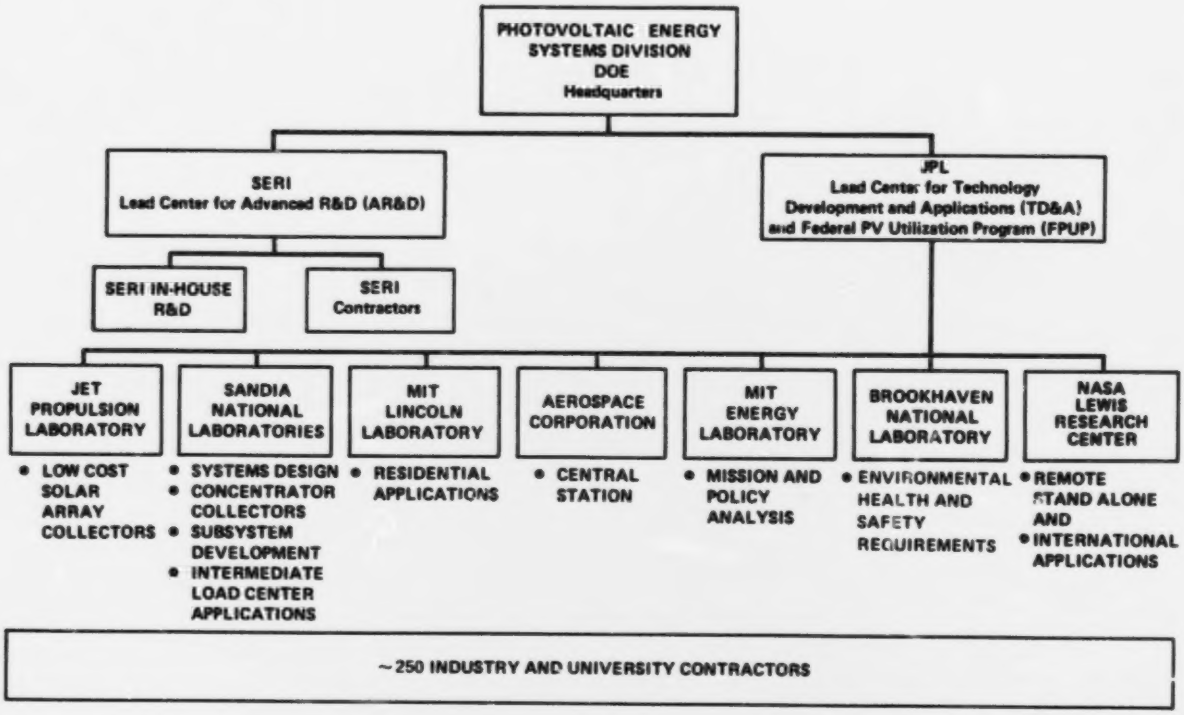
PHOTOVOLTAIC ENERGY SYSTEMS DIVISION DOE Headquarters
SERI Lead Center for Advanced R&D (AR&D)
JPL Lead Center for Technology Development and Applications (TD&A) and Federal PV Utilization Program (FPUP)
SERI IN-HOUSE R&D
SERI Contractors
JET PROPULSION LABORATORY
• LOW COST SOLAR ARRAY COLLECTORS
SANDIA NATIONAL LABORATORIES
• SYSTEMS DESIGN
• CONCENTRATOR COLLECTORS
• SUBSYSTEM DEVELOPMENT
• INTERMEDIATE LOAD CENTER APPLICATIONS
MIT LINCOLN LABORATORY
• RESIDENTIAL APPLICATIONS
AEROSPACE CORPORATION
• CENTRAL STATION
MIT ENERGY LABORATORY
• MISSION AND POLICY ANALYSIS
BROOKHAVEN NATIONAL LABORATORY
• ENVIRONMENTAL HEALTH AND SAFETY REQUIREMENTS
NASA LEWIS RESEARCH CENTER
• REMOTE STAND ALONE AND
• INTERNATIONAL APPLICATIONS
~250 INDUSTRY AND UNIVERSITY CONTRACTORS

Figure 2-2. Photovoltaics Program Organization

As part of the Tests and Applications/Industry Assistance stage, the feasibility of new system concepts is examined and confirmed through Initial System Evaluation Experiments (ISEE) involving real applications and actual users. System concepts of proven feasibility and embodying "technology ready" (TR) components are then subjected to Engineering Field Tests (EFT) designed to verify "system readiness" (SR). Mission analysis studies are carried out by PA&I to direct system development activities to the most promising applications. "Commercial readiness" (CR) is achieved when the products or systems are offered in a given application class for sale at a given competitive price.[1] This progression forms the basic Program approach for what is called the Research, Development, and Demonstration (RD&D) Process for Photovoltaic Components and Systems, as depicted in Figure 2-3. Out of this process emerges the set of generic milestones described above (See Table 2-1). The Photovoltaics Program is structured around the elements of the RD&D Process, and is scheduled by choosing dates for achievement of each major milestone in a given system application or component technology.[2]

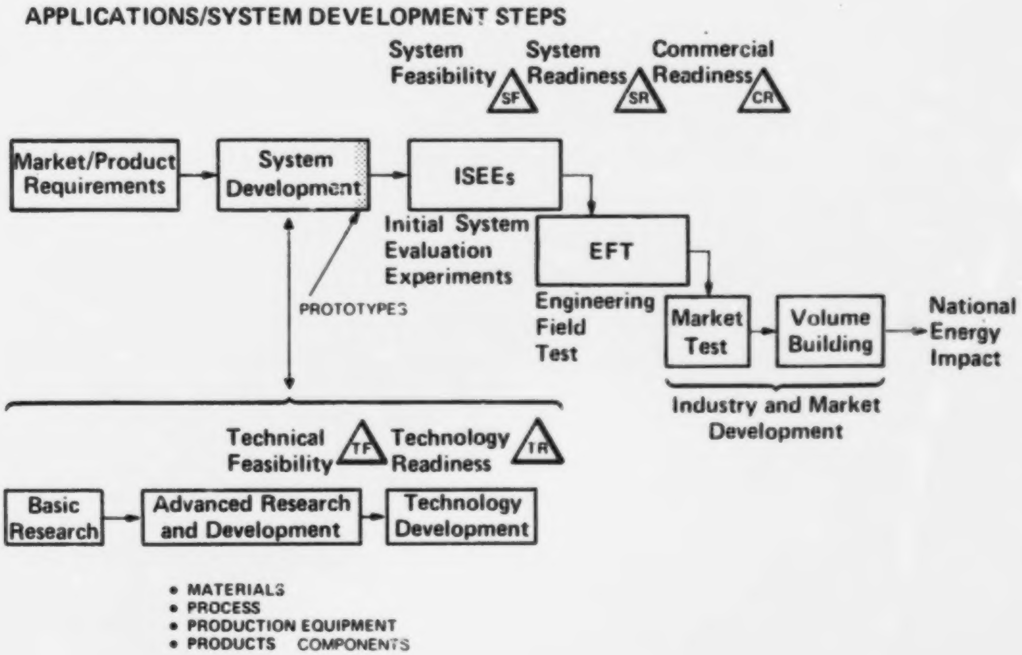
APPLICATIONS/SYSTEM DEVELOPMENT STEPS
System Feasibility
SF
System Readiness
SR
Commercial Readiness
CR
Market/Product Requirements
System Development
ISEEs
Initial System Evaluation Experiments
EFT
Engineering Field Test
Market Test
Volume Building
National Energy Impact
Industry and Market Development
PROTOTYPES
Technical Feasibility
TF
Technology Readiness
TR
Basic Research
Advanced Research and Development
Technology Development
• MATERIALS
• PROCESS
• PRODUCTION EQUIPMENT
• PRODUCTS COMPONENTS

Figure 2-3. Program Approach

---

[1] Applications for photovoltaics along with the near-, mid-, and far-term price goals for achievement of Program objectives will be discussed later.

[2] It is important to understand that different system and component technology options may be in different phases of the RD&D process. Certain photovoltaic systems, for instance, have already reached commercial readiness in remote stand-alone applications, while residential systems are only beginning to reach system feasibility. Flat-plate silicon modules and several concentrating collectors are approaching technology readiness for grid-connected applications while many other promising collector technologies are still in the advanced research and development stage, having not yet shown technical feasibility. These collector technologies are termed "advanced technologies" to distinguish them from the "baseline technologies" for which technical feasibility has already been proven.

Table 2-1. Key Generic Milestones in the Photovoltaic RD&D Process

Milestone	Definitions/Requirements
Technical feasibility (TF) of components	Technical feasibility is reached for a specific technology when stable and reproducible performance characteristics have been achieved; a laboratory-scale process has been defined that yields products with consistent characteristics; and analysis indicates that mass production is technically feasible and likely to yield a technically and economically viable product after suitable technology development.
Technology readiness (TR) of components	Technical readiness is achieved with a successful sub-scale demonstration of all the individual steps in a production process that would yield economically competitive and reliable products if produced in sufficient quantity; and when prototypes are available for intensive performance and reliability analysis.
System feasibility (SF)	System feasibility is achieved in a given application when a photovoltaic system concept is first carried through design, installation, and operation in an actual user's environment.
System readiness (SR)	System readiness is accomplished when fully integrated systems, using available technology-ready components or prototypes thereof, are designed, built and successfully operated in an actual user's environment.
Commercial readiness (CR) of components and systems	Commercial readiness in a given application class is accomplished when products or systems are offered for sale at a given price.

2. Applications

Applications for photovoltaics are being pursued in the following four sectors to support the accelerated transfer of technology to the marketplace:

(1) Grid-connected residences.

(2) Intermediate load centers.

(3) Central station power generating plants.

(4) Remote stand-alone power generating systems, including international applications.

The functional Subprogram elements, when overlaid with the four major application sectors, form the Program matrix shown in Figure 2-4. This, in turn, forms the basis for planning, coordination, and assignment of responsibility.

3. Price Goals

The objective of the DOE Photovoltaics Program, as stated previously, is to bring photovoltaic energy systems to the point where they are able to supply a significant portion of the nation's energy requirements at costs reasonably competitive with electricity from fossil and nuclear generating sources. To quantify this objective, DOE has adopted as an overall goal the displacement by photovoltaics of at least 1.0 quad per year of conventional, primary fuels by

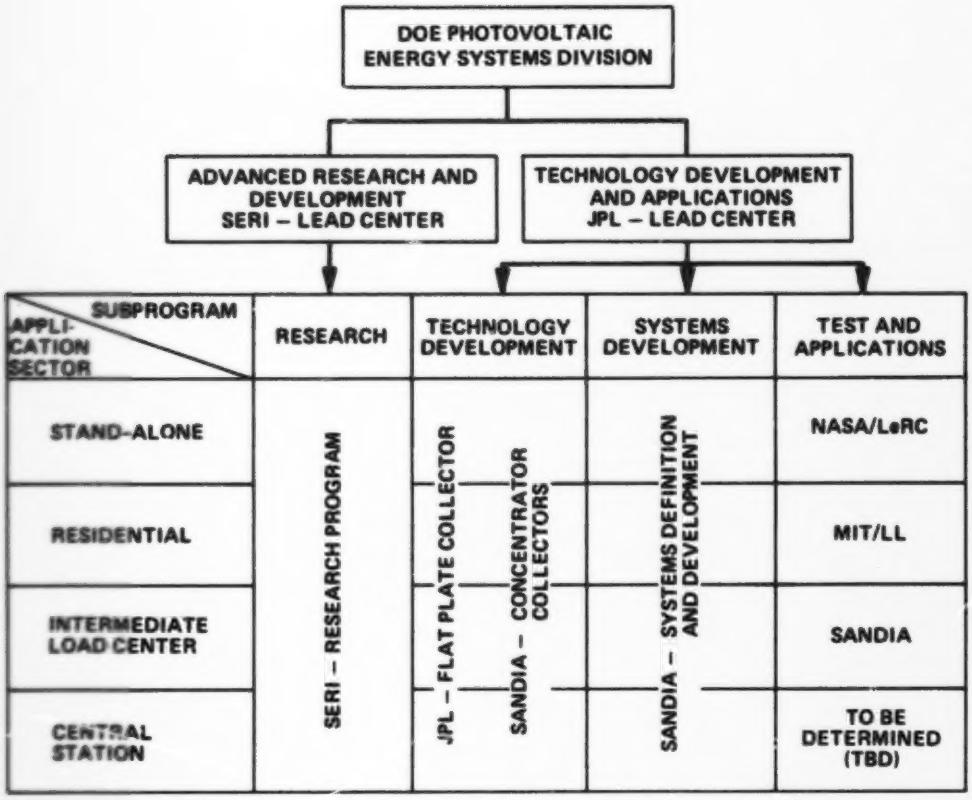
DOE PHOTOVOLTAIC ENERGY SYSTEMS DIVISION
ADVANCED RESEARCH AND DEVELOPMENT SERI – LEAD CENTER
TECHNOLOGY DEVELOPMENT AND APPLICATIONS JPL – LEAD CENTER
SUBPROGRAM
APPLICATION SECTOR
RESEARCH
TECHNOLOGY DEVELOPMENT
SYSTEMS DEVELOPMENT
TEST AND APPLICATIONS
STAND-ALONE
RESIDENTIAL
INTERMEDIATE LOAD CENTER
CENTRAL STATION
SERI – RESEARCH PROGRAM
JPL – FLAT PLATE COLLECTOR
SANDIA – CONCENTRATOR COLLECTORS
SANDIA – SYSTEMS DEFINITION AND DEVELOPMENT
NASA/LeRC
MIT/LL
SANDIA
TO BE DETERMINED (TBD)

Figure 2-4. Program Structure

the year 2000[3]. As such, a set of competitive or break-even price goals has been established for the near-, mid-, and far-term. These figures relative to each of the application sectors are depicted in Table 2-2.

It is anticipated that achievement of the collector and installed system price goals will make photovoltaic systems economically competitive with alternative energy sources for dispersed on-site applications as well as for central power generation. Commercial readiness for residential applications and intermediate-load-center on-site applications is expected to be reached in 1986 and for central-station applications in 1990. At these times, the Federal Government may choose among a number of incentives to accelerate the market penetration of photovoltaic systems.

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[3] 50,000 MW_p installed → 1 quad per year conventional fuels displaced (= ~180 million barrels of oil per year).

Table 2-2. Commercial Readiness Price Goals

Application and Year	Collector Price (FOB) ($/W$_p$)	System Prices* ($/W$_p$)	Production Scale (MW$_p$/year)
Remote Stand-Alone 1982	≤2.80**	6-13	
Residential 1986	≤0.70	1.60-2.20	100-1000
Intermediate Load Center 1986	≤0.70	1.60-2.60	100-1000
Central Station 1990	0.15-0.40	1.10-1.80	500-2500

*System price correlates with production scale

**All figures are quoted in 1980 dollars

SECTION III

PROGRAM HIGHLIGHTS

A. ADVANCED RESEARCH AND DEVELOPMENT

Implementation of the Advanced Research and Development Subprogram and associated planning, assessment and integration activities is the responsibility of the Photovoltaics Lead Center for AR&D, located at the Solar Energy Research Institute in Golden, Colorado. The major thrust of this subprogram is to achieve technical feasibility for various advanced-material technologies. At present, AR&D is directed toward investigation of advanced cell concepts, materials, and structures leading to very low-cost solar cell devices. The AR&D effort must demonstrate that these structures have a potential for adequately high conversion efficiency while retaining attractively low costs and high reliability. Specifically, these technologies will have demonstrated the potential of achieving stable and reliable devices with greater than 10% conversion efficiency and a collector cost potential of \$0.15 to \$0.40/W_p, which should allow system costs of \$1.10 to \$1.80/W_p. Thin-film structures in particular offer material conservation, simplified film growth techniques and the use of inexpensive substrates which are amenable to in-line, automated processing. Higher conservation efficiencies are also being sought through advanced technology cells for use with concentrated sunlight. These efforts will assist photovoltaics in expanding its commercial markets and make central utility applications viable.

The AR&D Subprogram is made up of three major elements: (1) advanced silicon, (2) compound semiconductors, and (3) technical support.

1. Advanced Silicon

The research on thin-film (less than 50 micrometers) polycrystalline silicon is concerned with obtaining large-grain films and cell efficiencies of more than 10% and emphasizing the fabrication of these devices on low-cost substrates. The achievement of cell efficiencies greater than 10% has been accomplished in FY 1980. Thin-film cells hold the promise of significantly reducing the cost of photovoltaic energy conversion, while maintaining the positive attributes generally associated with silicon such as abundance, relatively high efficiency and stability, and the existence of a broad technology base. As a result of an evaluation in FY 1979 of the polycrystalline-silicon task, exploratory development activities have been initiated with a goal of demonstrating technical feasibility by FY 1983. These activities are expected to provide experimental proof that laboratory-type cells exhibit reproducibility, stability, encapsulability, and adequate size, and meet Photovoltaics Program efficiency goals to enhance material transition from research and development to technology development. Hydrogenated thin-film (less than 2 micrometers) amorphous silicon is being studied to obtain an understanding of the fundamentals of the defect state passivation process which has led to efficiencies of greater than 6% for solar cells with areas of about 1 cm^2. This effort should result in the development of stable amorphous cells with an efficiency of 10%. Amorphous materials other than amorphous-silicon are also being investigated to find suitable materials with good photovoltaic properties. Because of their research similarities, they are included in the amorphous-silicon task. Candidate materials include amorphous gallium arsenide and boron.

2. Compound Semiconductors

The goals of the thin-film effort in the cadmium sulfide class of cells are to demonstrate suitable cell stability for large-area encapsulated cells and to achieve 8% conversion efficiency for small-scale arrays by the end of FY 1982. Concurrently, analyses evaluating the feasibility of low-cost production (\$0.15-\$0.40/W_p) are planned to evaluate further the appropriate performance and price characteristics of this technology.

Gallium arsenide research is directed toward the deposition of thin fi[illegible]ess than 8 micrometers) with large grain sizes, an understanding of the effects of grain boundaries on cell performance of thin-film, substantially single-crystal structures, and an investigation of several junction-formation techniques. Because of its steep absorption edge and high single-crystal efficiency, gallium arsenide offers the potential of a greater-than-12% efficient thin-film cell.

The emerging materials are promising new materials and device concepts for photovoltaic conversion which have potential for the long-term future. Among the materials being investigated are zinc phosphide, cadmium telluride, zinc silicon arsenide, copper oxide, cadmium sulfide/indium phosphide, copper selenide, and tungsten dixelenide. A program is underway to investigate device fabrication by chemical-spray and screen-printing techniques to test the feasibility of these low-cost fabrication processes for high-efficiency cells. The goal of this effort is to emphasize the most promising materials over the next few years so that at least one emerging material can reach technical feasibility by FY 1985-1987.

Research on advanced concentrator concepts is also being conducted. Multi-junction concentrator cells are being investigated for a possible efficiency of at least 30%. Other concentrating concepts such as the luminescent converter are also being studied for their possible potential.

The electrochemical photovoltaic cell program centers on fundamental studies of the semiconductor-electrolyte interface and its application to low-cost, stable, high-conversion-efficiency devices. The near-term goals of this effort are to develop a stable cell conversion efficiency of 10% in FY 1981 and 12% in FY 1983 using amorphous or polycrystalline, thin-film electrodes.

The innovative concepts program provides periodic solicitations to explore the feasibility and fundamentals of new photovoltaic concepts. Initial awards are small until the concept has been adequately explored for further work or rejection. To date, 26 awards have been made from two solicitations. Several of these awards have already resulted in significant developments that have been incorporated into other parts of the Program.

3. Technical Support

The measurements and evaluation task is in the process of developing a facility to provide measurement support both for researchers and for the internal evaluation of subcontractor-supplied photovoltaic research samples. Characterization of structural, chemical, optical and electro-optical properties will be performed regularly. Analysis of contractor-fabricated devices will provide a uniform measure for guiding and evaluating individual advanced technologies and the AR&D Subprogram as a whole, thus supporting short- and long-term planning. Development of new measurement techniques in support of photovoltaic material and device research will be undertaken. These include, but are not limited to, real-time resistivities on conducting and insulating substrates, measuring local carrier collection efficiency as a function of energy using a modulated electron beam, and continued development of a laser scanning technique to study properties of metallization and grain boundaries and their passivation.

The materials availability effort uses existing analysis methods and programs to screen selected material technologies initially for potential availability constraints. Identified materials problem areas will then be researched to understand the technical and economic issues affecting supply and price. Recommendations for mitigating options will be made based on this understanding.

Economic and policy analysis activities in the AR&D Subprogram include the preparation of a cost data base on material and manufacturing production technologies that are expected to be used in the commercial production of advanced photovoltaic modules. Currently available data are being collected, and areas where additional information is required for better cost estimates are being identified. This information will be integrated into a simple cost-estimation technique capable of providing complete module cost estimates and cost sensitivity analyses. Decision methodologies for research and development programs will be studied as they relate to advanced photovoltaic technologies, and analysis will be performed to support advanced photovoltaic research and development decisions.

Environmental, health and safety (EH&S) studies are being conducted to identify possible harmful emissions and waste products resulting from advanced material cell production processes. Health, safety and environmental significance will be assessed through synthesis of appropriate literature. Environmental regulations that may apply to probable emissions and effluents are being identified, and National Environmental Policy Act and Department of Energy-National Environmental Policy compliance procedures will be reviewed for this applicability to the deployment of advanced-material cells. This environmental review activity precedes detailed quantitative assessments.

System support efforts for technologies in the AR&D Subprogram are addressing the anticipated performance of advanced photovoltaic cells and devices when used in a total photovoltaic energy system. The special effects of system and subsystem interactions on the performance of specific advanced photovoltaic cells and devices, if any, and the effects of potential application loads and load profiles on the expected advanced cell and device performance will be considered.

Significant achievements in FY 1980 include:

(1) Initiation of Exploratory Development (ED) for thin-film, polycrystalline silicon photovoltaic devices. The objective of this program plus subsequent phases is to demonstrate a module cost feasibility of less than $500/peak kW_p (1980$).

(2) Demonstration of 10.2% cell efficiency in $Cu_2S/(Cd,Zn)S$, up from 8% in 1979.

(3) Development of 6.3% amorphous silicon cell area greater than 1 cm^2, up from 5% in 1979. Also, deposition time for preparing hydrogenated amorphous silicon material reduced to 6 minutes from greater than 30 minutes.

(4) Development of Edge-Supported Pulling (ESP) technique for silicon sheet production has been developed with cells having 13.8% efficiency demonstrated.

(5) Demonstration of 17% GaAs thin-film solar cell.

(6) Improvement of luminescent solar concentrator system efficiencies improved from 2.5 to 3.2% (30% improvement).

(7) Improvement of photoelectrochemical thin-film cell efficiencies from ≤4% to ≥6% (polycrystalline materials and photoelectrochemical single-crystal efficiencies from ≤6% to ≥10%.

(8) Demonstration of 12% polycrystalline silicon thin-film cells, up from 10.1% in 1979.

(9) Bonding together of two separate cell materials to form a cascade solar cell.

Also during this period, studies were conducted on semiconductor theory (theoretical techniques for determining the electronic structures for semiconductor surfaces and interfaces were completed), high efficiency cells, thin films, silicon purification, thick-film technology, device processing surface and interface analysis, and measurement techniques.

The Photovoltaics Advanced Research and Development goals for FY 1981 encompass a wide range of activities that are essential for the continued and timely development of set priorities for mid- to long-term activities. They include:

(1) Demonstrating a 10% efficient electrochemical cell.

(2) Performing a major review of R&D material technology options.

(3) Demonstrating three types of thin-film cells with 10% efficiency on 1 cm^2.

(4) Assessing technology options for high efficiency concentrators.

(5) Initiating programs for development of dyes for use in luminescent solar concentrators.

B. COLLECTOR TECHNOLOGY DEVELOPMENT

Implementation of the Collector Technology Development Subprogram as well as Systems Development, Tests and Applications/Industry Assistance and the associated Program Planning, Analysis and Integration activities are the responsibility of the Photovoltaics Lead Center for Technology Development and Applications, located at the Jet Propulsion Laboratory in Pasadena, California.

The major objective of the Collector Technology Development Subprogram is to develop two or more technology options capable of meeting the Program goals. To this end, several promising collector technologies are being pursued simultaneously. The collector price goals outlined in Table 2-2 are elaborated on to include the first \$0.15 to \$0.40/W_p thin-film collector technology readiness by FY 1986, which could allow commercial readiness to be established in FY 1990.

The emphasis of the Collector Technology Development Subprogram has been in three main areas:

(1) Flat-plate collectors.

(2) Concentrator collectors.

(3) Photovoltaic/thermal collectors.

1. Flat-Plate Collectors

The Low-Cost Solar Array (LSA) Project is sponsoring the development of a variety of solar-cell types made from both single-crystal and semicrystalline silicon ingots, as well as silicon ribbons, to meet the 1982 and 1986 collector price targets. Currently, it is believed that the well-understood advanced silicon technology has the best probability of becoming technology-ready at \$0.70/W_p in the short term (by 1982). Advanced research and development efforts underway in other areas, such as thin-film photovoltaics, are expected to meet the 1986 technology readiness goal of \$0.15 to \$0.40/W_p.

The LSA Project has four technology development activities; each activity aims to reduce the cost of one phase in the conversion of silicon into a working solar electric collector. The four principal tasks are: (1) the production of low-cost polysilicon, (2) the formation of large-area crystalline sheets for the production of solar cells, (3) the development of solar cell and collector encapsulation materials and processes, and (4) the development of low-cost collector fabrication techniques via automation.

Accomplishments during FY 1980 are as follows:

(1) Technology readiness for \$2.80/W_p module technology was announced in September 1980. If scaled to production quantities with the current technology, modules could be profitably produced and sold at that price by late 1982.

(2) Several silicon material processes for producing semiconductor grade and solar cell grade silicon have been under development. The most promising one uses the silane process. This process should establish technology readiness for producing semiconductor-grade silicon at a price less than \$14/kg (1980\$) by the end of FY 1982. Prices in 1979-1980 ranged as high as \$100/kg. This objective will be accomplished by the successful operation of an experimental process system development unit (EPSDU). During FY 1980, the construction of the EPSDU was authorized based on the successful operation of a product development unit (PDU), a small-scale experimental process demonstration.

(3) Efforts in large-area crystalline sheets continue to show promise for the production of large-area silicon sheet suitable for low-cost and high-efficiency cells. These include improvements to reduce the cost of producing and slicing large Czochralski ingots as well as the development of direct sheet growth techniques such as edge-defined film-fed growth (EFG), web dendritic growth and polycrystalline sheet material (SEMIX). Recent accomplishments include the following: 150-kg Czochralski ingots have been produced from a single crucible; ingot wafering of 22 wafers/cm has been demonstrated; the web dendritic growth process has been demonstrated using melt replenishment and semiautomated operation.

(4) Although glass continues to be the most effective cover for terrestrial modules, the two non-sticking compounds, ethylene-vinyl-acetate (EVA) and ethylene-propylene-rubber (EPR) have emerged as potential promising lower-cost covers. Qualification of these two compounds is continuing.

(5) Module experimental process system development unit (MEPSDU) contract activities have been initiated. These module manufacturing pilot lines start with large-area sheet material and produce modules in one process sequence. Evaluation of the full process results is planned for late FY 1982 as part of meeting the $0.70/$W_p$ technology readiness milestone.

2. Concentrator Collectors

The Concentrator Collector Project is developing silicon solar cell concentrator arrays and advanced solar cell devices for concentrator arrays which can meet the 1982 and 1986 collector price targets. The project has three technology development task activities. These are: (1) concentrator solar cell technology and solar cell assembly development, (2) solar concentrator technology development, and (3) concentrator array subsystem technology development.

During 1980, significant advancement has been made in each of the areas listed:

(1) Several solar cell manufacturers have developed concentrator solar cells of 19-20% efficiency for use with concentration ratios ranging from 20-40X and also for 600X concentration. These results are very encouraging, demonstrating that silicon solar cells are practical for high concentration applications.

(2) Automatic solar cell assembly development is continuing to show promise, especially for line focus receiver applications.

(3) Optical concentrators with 80-90% efficiency and low-cost potential have been demonstrated. The most promising concentrator designs are linear-focus Fresnel lens, point-focus Fresnel lens, and reflective parabolic troughs.

(4) Full-scale concentrator arrays of 2.5- and 10-kW peak power levels have been fabricated and tested, and contracts have been placed for the installation of a total of 1 MW of concentrator array fields.

(5) Technology readiness for $2.80/$W_p$ collectors for three concentrator designs, linear focus troughs, linear focus Fresnel lens and point focus Fresnel lens has been announced. The technology readiness statement is based on the following:

Array efficiency:	10-12%
Silicon solar cells:	$0.35/cm^2
Installed array cost:	$400/m^2

3. Photovoltaic/Thermal

The Photovoltaic/Thermal (PV/T) Hybrid Collector effort is developing a collector and heat transfer system which may possibly offer cost advantages over side-by-side photovoltaic and thermal systems. These cost advantages would result from the commonality of hardware designs, production methods, and installation practices. There would also be advantages in specific installations where there are, for example, roof area limitations.

Photovoltaic/thermal collectors usually cannot attain the thermal conversion efficiency of a thermal-only collector system because the photovoltaic cells are not good thermal absorbers and occupy major portions of the collector surface. Likewise, the photovoltaic cell may be required to operate within constraints and configurations that are not optimum for electric energy conversion. Thus, the PV/T collector is being examined critically to adequately delineate its cost-effectiveness.

During FY 1980, activities have been directed to generate a limited quantity of hardware for quantitative performance and economic evaluation, including a number of studies, computer simulations keyed to specific locations, plus application and customer requirements analyses.

C. SYSTEMS DEVELOPMENT

The Systems Development Subprogram is responsible for the definition and limited testing of complete prototype photovoltaic systems which meet all requirements for technical, commercial, and social viability. The process by which such systems are engineered includes:

(1) Systems Engineering.

  (a) Requirements Definition.

  (b) Design and Analysis.

  (c) Evaluation.

  (d) Design and Pricing Tools.

  (e) Codes and Standards.

  (f) Environmental, Health, and Safety Requirements.

  (g) Performance Assurance/Reliability.

(2) Subsystems Development.

  (a) Array.

  (b) Power Processor.

  (c) Storage.

1. Systems Engineering

Systems Engineering begins by establishing initial performance requirements for systems and subsystems for each of the four PV applications sectors. These requirements constitute criteria which ensure that the systems for each sector will be technologically and economically competitive producers of energy. Model systems are designed and analyzed on the basis of the initial performance requirements. Such systems provide an opportunity to evaluate and refine initial system and subsystem price goals in support of goal achievement. Evaluation of systems designed according to established performance requirements serves to validate or justify refinements in those requirements, while yielding test data to support improved system reliability. Development of simplified sizing and design procedures is intended to accelerate wide acceptance of photovoltaics through facilitating their adoption by architects, developers and contractors. Similarly, the support of codes and standards development is intended to foster market penetration through the development of appropriate codes prior to the broad-scale commercial appearance of PV systems. The early consideration of environmental, health, and safety requirements permits the development of systems which are occupationally and socially attractive. Finally, adequate consideration of performance and reliability issessential to meeting life cycle costs goals.

During FY 1980, the Systems Development Subprogram has pursued a strategy designed to specifically address each of the elements listed earlier. In the Systems Engineering area, appropriate application sectors have been defined, and in-depth system definition and design studies are now underway in each. Both residential and intermediate baseline designs have been completed, and more are scheduled for FY 1981. Basic performance requirements have been developed for residential arrays, and similar efforts are in progress to determine requirements for intermediate sector arrays. Activities are also in progress to develop costing and simplified sizing and design procedures. Interim performance criteria have been compiled which will assist in developing model building codes and standards. Test facilities have been established at several PV Program Field Centers for evaluating complete photovoltaics systems, including a station in the northeast specifically designed to test residential prototype systems. Several small- and intermediate-scale system field tests have been established and will operate through FY 1981. The reporting and evaluation of results is under the purview of the Test and Applications/Industry Assistance Subprogram.

2. Subsystems Development

Subsystems Development addresses array, power processor, and energy storage subsystems appropriate to the achievement of all cost, performance, and reliability goals for PV systems. Representative subsystem activities include the examination of design and cost trade-offs, evaluation of prototype development of installation and maintenance strategies, and establishment of safety criteria.

During FY 1980, subsystem activities directed toward substantially improved performance concurrent with reduced cost have produced results in a number of areas. Several attractive low-cost array structures are being refined and installation methods developed, and innovative array circuit designs promise to improve reliability and reduce maintenance costs. Several issues concerning the integration of photovoltaic systems into the utility grid will receive increased attention in FY 1981, including utility requirements on the quality of the power provided to the grid, electrical code rerequirements, and safety issues. These issues are being addressed in cooperation with the electric power industry to ensure the timely adoption of meaningful performance requirements for power conditioning subsystem development.

Finally, the appropriate role of energy storage in several application sectors is also being examined. Already well established for remote stand-alone applications, the requirements for storage subsystems in utility-interactive photovoltaic applications are being investigated. In addition, several storage subsystem concepts, including advanced batteries and flywheels, are being studied for their potential in a variety of photovoltaic applications.

D. TESTS AND APPLICATIONS/INDUSTRY ASSISTANCE

The objective of the Tests and Applications/Industry Assistance Subprogram is to respond to requirements for experimental information by defining, planning, developing, and implementing tests and applications experiments in all application sectors. In addition to the systems designs information requirements satisfied by the Subprogram, these experiments incorporate institutional guidelines and information requirements, as well as information furnished on cost, performance, reliability, user acceptance, and institutional aspects. The Subprogram is also responsible for fostering the development of a supply infrastructure for system-ready technology, in conjunction with promoting widespread awareness of photovoltaic systems. Activity is focused into three major areas:

(1) Experimentation.

(2) Data Analysis and Information.

(3) Industry Assistance.

During FY 1980, two significant applications became operational: (1) Natural Bridges National Monument Visitors Center in Utah which, at 100 kW_p, is currently the world's largest system; and (2) the utility interactive John F. Long model home in Phoenix, Arizona.

The first audit of an operational application, Mt. Laguna Air Force Radar Station, was completed. The intent of the audit is to produce a systematic method for the gathering of data by which to evaluate an application. Audits were initiated at the following applications: Mead, Nebraska; Natural Bridges, Utah; Bryan, Ohio; University of Texas at Arlington; and Schuchuli, Arizona. By November 1979, all nine contracts for experiments under the Program Research and Development Announcement (PRDA) were underway for fabrication of systems to be installed in a variety of applications, to be operated for one to two years and evaluated to obtain technical performance data. These experiments are significant in that they represent a shift in the PV Program from remote stand-alone type applications to grid-connected. The PRDAs, which total about 750 kW_p, are scheduled for operation in FY 1981.

The grants programs at Mississippi County Community College (240 kW_p) and Northwest Mississippi Junior College (151 kW_p) are expected to become operational in FY 1981. A new grants project, Georgetown University, will be initiated with a preliminary design phase occurring in FY 1981.

The largest application in the world at 350 kW, the Soleras Project in Saudi Arabia, is expected to become operational in FY 1981. Additional international cooperation will be reflected in program support to the 1.15-MW Italian Delphos Project in the form of design consultation. Design and consulting support is also planned for the MX Missile System Renewable Energy Source Applications.

During FY 1981, attention will be focused on the fostering of an industry assistance program to encourage and facilitate timely supply-side industry investment in the use of the low-cost technology developed under the National Photovoltaics Program. Data requirements for the industry task will be compiled and interfaced with other industry surveys currently underway within the DOE's Office of Policy and Evaluation and the Solar Energy Industry Association.

E. FEDERAL PHOTOVOLTAICS UTILIZATION PROGRAM

The FPUP effort was established in 1978 to procure photovoltaics systems for use on federal facilities. The objectives established in that legislation provide for the acquisition of photovoltaic solar electric systems at an annual level substantial enough to allow the use of low-cost production techniques by the suppliers of such systems. Further, the goals of the Program, as established by Congress, are to:

(1) Accelerate the growth of a commercially viable and competitive industry to make photovoltaic solar electric systems available to the general public as an option in order to reduce national consumption of fossil fuel.

(2) Reduce fossil fuel costs to the Federal Government.

(3) Stimulate the general use within the Federal Government of methods for the minimization of life cycle cost.

(4) Develop performance data on the program.

The program is divided into cycles. The various cycles have different emphases, ranging from small remote systems in Cycle I to larger, grid-connected applications in Cycle IV.

Cycle I was initiated in fall 1978. It resulted in the receipt of federal agency proposals for 1,603 photovoltaic projects. Of these, 1,538 were determined to be cost-effective at current installed system prices and were approved for funding at a total cost of about $10 million. Total kW_p output for Cycle I is 216. Cycles II and III were initiated in FY 1979. Cycle II proposals from federal agencies were received in June 1979, and $5 million in additional projects was approved.

During FY 1980, in response to the FPUP Cycle III request, 432 proposals were received from federal agencies for intermediate and remote stand-alone applications. Twenty-nine of these applications were selected, representing 13 federal agencies. The selected applications had a total estimated cost in excess of $4.9M and a total estimated power of 118 kW_p. For FPUP Cycle IV residential and selected intermediate grid-connected applications, 62 proposals with an estimated value of $62M were received from federal agencies. From the Cycle IV proposals, seven applications with an estimated value of $4.5M and a total estimated power of 145 kW_p were selected by an evaluation committee in June 1980.

In summary, 2,772 photovoltaic applications have been funded under the Federal Photovoltaic Utilization Program. These applications represent approximately 660 kW_p. Of these, 123 applications with a total power rating of 10 kW_p have been installed and are operating successfully. Some typical examples representing classes of applications with high follow-on potential are described in the following paragraphs:

(1) Two National Oceanic and Atmospheric Administration (NOAA) weather station applications have been operational at the Severe Storms Research Laboratory (SSRL) at Norman, Oklahoma, for 1 year. SSRL is planning to procure 50 follow-on systems for studying weather patterns across central Oklahoma.

(2) At Bay St. Louis, Mississippi, NOAA is testing a PV-powered weather monitor buoy. Upon completion of testing, this buoy will be deployed in the Gulf of Mexico for 2 years of operation without servicing. Based on this application, NOAA has proposed the use of photovoltaic systems for the "Seaman's Program."

(3) The Coast Guard has performed complete qualification testing for five navigational aids which are presently being installed. These are prototypes of 14,000 follow-on systems. FPUP is funding 1,400 of these systems.

(4) The Naval Weapons Center (NWC) at China Lake, California has installed three emergency radio applications to provide communication for persons lost in remote desert areas of the test site. NWC has also installed aircraft warning lights on hills surrounding the El Toro Marine Air Station.

(5) To maintain forest fire surveillance of National Forest areas, the U.S. Forest Service uses forest lookout towers which require power for lights, refrigeration, and radio communication. Seven of these in Idaho are powered by FPUP-funded PV power systems.

(6) The National Park Service has repeater applications to provide routine as well as emergency communication from remote sites in Hawaii, Michigan, and Texas.

(7) To provide weather data from remote areas in Montana, the Water and Power Resources Service has fielded 49 FPUP automatic, unmanned weather station applications. Water and Power Resources Service plans to have 201 follow-on applications operational by the third quarter of 1982.

(8) In Zion National Park, Utah, the Environmental Protection Agency has installed a PV power system for a visibility monitor to evaluate air quality.

Contracts for 90% of the FPUP systems will be awarded by the end of calendar year 1981. All applications are scheduled to be operational by the first quarter of CY 1983.

The first FPUP Newsletter, providing information on federal agency application activities as well as near-term Federal agency procurements, was distributed in October 1980.

The FPUP continues to provide support to agencies as systems are procured and installed. The applications are monitored on a regular basis, and a set of performance data is being developed to support improved reliability in future applications.

SECTION IV

SUMMARY

In keeping with the goals and intent of the RD&D legislation, the objective of the U.S. Department of Energy's (DOE) Photovoltaics Program is to develop photovoltaic energy systems capable of supplying a significant portion of the nation's energy requirements. The Program goal is to foster the early development of economically competitive, commercially available systems capable of supplying safe and reliable electrical power to a wide variety of users. This will be accomplished through substantial research, development, and demonstration (RD&D) efforts aimed at achieving major cost reductions in both components and systems.

Distributed grid-connected and total energy residential systems should be able to displace significant amounts of centrally generated electricity, first in the southwest and southeast and subsequently throughout much of the United States. Intermediate-size commercial, institutional, and industrial on-site systems should provide a similar option. Finally, utilities should ultimately be able to augment their generating capacity with larger-scale systems. As part of the DOE sequence of Advanced Research and Development, Collector Technology Development, Systems Development, and Tests and Applications/Industry Assistance, real-world testing is being pursued with residential, industrial, institutional, and commercial systems to establish their feasibility and readiness to meet market economic and other requirements.

To stimulate and accelerate the growth of the domestic photovoltaics industry in the early to middle 1980s, the Program is also developing and encouraging the use of photovoltaics in remote stand-alone international applications and in applications within the Federal Government.

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PHOTOVOLTAIC ADVANCED RESEARCH AND DEVELOPMENT

The Photovoltaic Advanced Research and Development program is managed by the Solar Energy Research Institute (SERI) under contract to the Department of Energy. Active contracts administrated by SERI in FY 1980 are summarized on pages 2 through 154 inclusive. Listing is alphabetical by contractor name.

SERI

Photovoltaics AR&D Lead Center

TITLE: Mechanism of Preparation of Photovoltaic Amorphous Silicon Cells

CONTRACT NUMBER: XS-9-8041-12

CONTRACTOR (NAME AND ADDRESS):
Aerochem Research Laboratories, Inc.

P.O. Box 12
Princeton, NJ 08540
TELEPHONE: (609) 921-7070
PRINCIPAL INVESTIGATOR: H. Calcote

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401
FTS 327-1497
TELEPHONE: (303) 231-1497
PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:
FROM: Oct 1980 TO: Oct 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	100,000	SERI
81	80,000	SERI

SUMMARY:

The objectives of this program are to determine the chemical mechanism by which photovoltaic amorphous silicon films are formed in glow discharges of silane and to identify the relationship between the chemistry of the process and the performance of the resulting devices. The main tool that is used in this study is an ion and molecular beam mass spectrometer. Ions and neutral species are sampled through a small hole in the substrate being coated under a variety of discharge conditions (both dc and rf glow discharges are used). Devices are made under identical conditions as for the mass spectrometric study and their performance correlated with the discharge chemistry. To help understand the mechanisms involved, simulation experiments are carried out in which some of the species normally occurring in silane discharges are externally produced and allowed to react. The ultimate goal of the work is to make more efficient solar cells through an understanding of the silicon film formation process.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Photoelectrochemical Solar Cells Based on d-Band Electrochemistry at Transition Metal Diselenides

CONTRACT NUMBER: XW-0-9299

CONTRACTOR (NAME AND ADDRESS):
Ames Lab - USDOE
Iowa State University
Ames, Iowa 50011

TELEPHONE: FTS 865-7659

PRINCIPAL INVESTIGATOR: Dr. Bruce Parkinson

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1369

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 8/15/80 **TO:** 6/14/81

PROBABLE PROJECT COMPLETION DATE: 6/14/81

AREA/TASK: Compound Semiconductor/Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE
79	86,000	SERI
80	112,950	SERI

SUMMARY:

Evaluate and develop the transition metal diselenides WSe_2 and $MoSe_2$ as stable photoelectrodes in liquid junction solar cells.
The approaches which will be used are:

a. Grow large single crystals on which device limiting properties can be studied.
b. Characterize the photochemical stability of these materials using rotating ring-disc analysis.
c. Characterize the transport properties of the layered compounds as a function of impurities and defects.
d. Characterize the surface electronic structure in situ by high resolution photo-current measurements.
e. Seek to minimize degradation through edge reaction by passivating organics.
f. Investigate thin layer electrodes using these materials.

Ames has succeeded in growing high quality WSe_2 and $MoSe_2$ single crystals by the closed space vapor transport technique and has obtained efficiencies of up to 10% and 9.5% respectively in electrochemical photovoltaic cells containing a 2 M NaI/0.01MI_2 aqueous electrolyte. Ames has also succeeded in partially passivating surface defects against recombination by the partial intercalation of t-butyl pyridine.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Conceptual Design Study of the Magnetoplasmadynamic Deposition of Silicon
CONTRACT NUMBER: XJ-0-9051-1

CONTRACTOR (NAME AND ADDRESS):
AMEX Systems, Inc.
3355 El Segundo Boulevard
Hawthorne, CA 90250

TELEPHONE: (714) 751-3660
PRINCIPAL INVESTIGATOR: Gordon Cann

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7299
PROJECT ENGINEER: J. B. Milstein

CURRENT CONTRACT PERIOD:
FROM: 5/80 TO: 11/80

PROBABLE PROJECT COMPLETION DATE: 11/80

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 194,051	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY

The objectives of this program are to evolve the necessary cost effective equipment designs and define laboratory experiments to prove the deposition of silicon by the magnetoplasmadynamic process. The program will address the feasibility of producing the desired quality of the silicon film by this novel process. The program has been divided into four research tasks: (1) Conceptual Design of the Magnetoplasmadynamic System; (2) Theoretical Studies Relating to the Magnetoplasmadynamic Deposition Process; (3) Development of a Program Plan; and (4) Cost Analysis.

The technical approach planned is to conduct a thorough review of related silicon thin film deposition research, to relate results and theories to the magnetoplasmadynamic process, and to predict the film crystallinity expected on the basis of kinetic and thermodynamic considerations. The design of the deposition system and components will emphasize system cost and reliability, and the optimal selection of a liquid, vapor, or solid silicon feed system. The program plan will include the development schedule of a deposition system to demonstrate the feasibility of producing low cost silicon photovoltaic devices by a magnetoplasmadynamic process. A detailed experimental program will be developed with technical milestones for indices of progress. The performance regime being considered for the magnetoplasmadynamic deposition system includes a deposition rate of 1 micron/sec, a deposition area of 1 m^2, operating power of 100 kw, 80% power efficiency, and an monoenergetic particle beam having 10 eV energy per particle.

The theoretical analysis required has been completed and is in the process of being communicated to SERI. The development of a program plan and cost analysis are in progress.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Improved Slicing Method for Silicon
CONTRACT NUMBER: XS-0-9010-1

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corporation
15251 East Don Julian Road
City of Industry, CA 91746

TELEPHONE: (213) 968-6581
PRINCIPAL INVESTIGATOR: S. I. Soclof

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 3/15/80 **TO:** 3/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/High Efficiency Concentrators

CONTRACT FUNDING:

FY	$	SOURCE:
80	94,166	SERI

SUMMARY:

The objective of this is to explore orientation-dependent-etching (ODE) as an improved slicing method to provide thin silicon slices (25-50 μm) with increased yields (4-10 m^2/Kg), and suitable for processing into high efficiency solar cells.

The technical approach in this project consists of the following tasks:

A. Selection of the best ODE conditions i.e., optimization of etching conditions including chemistry, concentration, temperature, additives, agitation, and external controls; selection of the best mask material; and determination of a method for providing highly accurate crystallographic alignment. The ODE parameters are to be optimized for the best combination of etch rate and etch ratio (ratio of sideways/downwards etching). Higher slicing yields require high etch ratios.

B. Fabrication of solar cells, using ODE-slices, so as to select a process sequence best suited to the ODE procedures.

C. Evaluation of the cells produced for photovoltaic and other important parameters.

D. Application of the experience gained in the prediction of scale-up possibilities, in terms of costs, throughput and cell efficiency.

Several parallel tests are in progress to resolve the critical steps needed to provide effective slicing. Preliminary work has continued tests begun before the subcontract was awarded. A 30% solution of KOH in water, heated to around 80°C, was selected for its reasonably fast etch rate (1-2μm/min) with promise of meeting other ODE goals. A suitable etchant mask must meet several requirements. It must prevent etching of silicon in regions other than the etch-slots, must adhere well to the silicon, must not be excessively thick, must be capable of selective removal in fine lines, and must be compatible with a low-cost solar cell. Many different types of mask materials have been tested, including organic coatings, metal layers, oxides, and nitrides. The most promising so far is a combination of thermal SiO_2 and CVD Si_3N_4. Tests are under way to develop a convenient, simple, yet highly accurate process for aligning etch-slot along <111> directions in the (110) surface plane.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Computer Modelling of Amorphous Materials for Photovoltaic Conversion
CONTRACT NUMBER: DS-0-9011-1

CONTRACTOR (NAME AND ADDRESS):

Argonne National Laboratory
9700 South Cass Ave.
Argonne, IL 60439

TELEPHONE: (312) 972-5514
PRINCIPAL INVESTIGATOR: Dr. Lester Guttman

DIRECTING ORGANIZATION AND ADDRESS:

SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: FTS 327-7039 (303) 231-7039
PROJECT ENGINEER: T. McMahon

CURRENT CONTRACT PERIOD:
FROM: Oct 1 1980 **TO:** Sept 30 1981

PROBABLE PROJECT COMPLETION DATE: Sept 30 1981

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	60,000	DOE
81	60,000	SERI

SUMMARY:

Amorphous silicon-hydrogen alloys having shown promise as material for cheap and efficient photovoltaic cells, it is desirable to understand their electronic structure in anticipation of problems that will arise in practice. We construct computer analogues that are faithful representations of the atomic structure of pure amorphous Si, and compute from first principles the electronic wave functions and level energies of examples that contain hydrogen or that are defective in various ways. The results are expected, first, to aid in the interpretation of the effects of hydrogen on electrical resistivity and photoconductivity, and second, to provide guidance in understanding the relation of the transport properties of these materials to their composition, thermal history, and to other parameters of the fabrication process.

The modelling program is being closely integrated with concurrent work on preparation of amorphous silicon films and neutron diffraction studies of their structure (supported by the Division of Basic Energy Sciences).

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Electrodeposited Amorphous Silicon For Solar Cell Applications

CONTRACT NUMBER: XS-9-8249-1

CONTRACTOR (NAME AND ADDRESS):
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
TELEPHONE: (614) 424-5395
PRINCIPAL INVESTIGATOR: A.E. Austin

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1370
PROJECT ENGINEER: Jack Stone

CURRENT CONTRACT PERIOD:
FROM: 9/79 TO: 9/80

PROBABLE PROJECT COMPLETION DATE: 9/80

AREA/TASK: Advanced Silicon/
Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	297,730	DOE
80	308,072	SERI

SUMMARY:

The overall objective is to evaluate the photovoltaic properties and practicality for attaining a minimum of 10 percent efficiency in solar cells fabricated from electrodeposited amorphous silicon.

The program proposed for the development and the evaluation of electrodeposited, amorphous silicon for thin-film solar cells is divided into four tasks with the following objectives:

Task 1. To develop semiconductor doping of electrodeposited, amorphous silicon with controllable electronic properties of low cost substrates.
Task 2. To determine the physical and electronic properties of doped electrodeposited amorphous silicon.
Task 3. To develop Schottky barrier and p-n junction cells from electrodeposited, amorphous silicon.
Task 4. To evaluate the solar cell efficiency parameters of solar cells of electrodeposited, amorphous silicon.

For the doping of electrodeposited silicon, the electrolytic reduction and codeposition of possible n$^-$ and p$^-$ type dopants has been investigated. Three dopants B, Li, and Ga were found that could be codeposited with the silicon. Annealing was investigated for activation of these dopants in the silicon.

The deposition parameters of temperature and cathode substrates were studied. The hydrogen content of electrodeposited silicon was found to decrease from about 30 atom percent at 35°C with increasing temperature. The deposition onto an aluminum substrate was demonstrated in addition to the prior use of titanium and titanium alloy substrates.

The electronic properties of doped deposits were studied by differential capacitance and Schottky diode measurements. The dopants were found to be activated by annealing in the range of 350 to 400°C. This was also found to be the range for the start of hydrogen release from the silicon. Both n$^-$ and p$^-$type doping has been demonstrated.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Stability of Cadmium Sulfide/Copper Sulfide Solar Cells
CONTRACT NUMBER: RZ-0-9169

CONTRACTOR (NAME AND ADDRESS):
Battelle-Columbus Laboratories
505 King Ave.
Columbus, Ohio 43201

TELEPHONE: (614) 424-7481
PRINCIPAL INVESTIGATOR: Gerald T. Noel

DIRECTING ORGANIZATION AND ADDRESS:
SERI/Photovoltaics Program Office
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 8/12/80 TO: 8/11/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
80	368,061	SERI

SUMMARY:

The general objective of this project is to determine the viability of fabricating high efficiency CdS/Cu2S solar cells with operational lifetimes of the order of 20 years or more. Specific objectives are: (1) identify major intrinsic and extrinsic degradation modes; (2) determine physical, chemical, and mechanical processes which lead to device degradation; (3) make projections on the performance of cells over a 20 year period; (4) assess the potential for producing stable low-cost cells.

A preliminary test plan has been designed to address the above objectives. It includes: (1) device characterization by current-voltage and capacitance-voltage measurements, laser scans, etc.; (2) material analysis by SEM, SIMS, Auger, etc.; (3) stress tests under various temperatures, ambients, light intensity, electrical loading, and mechanical flexing.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE The Evaluation of Critical Materials for Photovoltaic Cells

CONTRACT NUMBER DS-9-8137-1 under DOE prime contract with Battelle DE-AC06-76RLO-1830

CONTRACTOR (NAME AND ADDRESS)
Battelle Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352

TELEPHONE 509-942-4348 FTS 444-4348

PRINCIPAL INVESTIGATOR: R. L. Watts

DIRECTING ORGANIZATION AND ADDRESS:
PV Analysis and Evaluation Branch
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: 303-231-1392 FTS 327-1392

PROJECT ENGINEER: S. R. Nagy

CURRENT CONTRACT PERIOD:
FROM: 5/15/79 TO: 2/14/81

PROBABLE PROJECT COMPLETION DATE: 2/14/81

AREA/TASK:
Technical Support/Availability of Materials

CONTRACT FUNDING:		SOURCE:
FY 79	$ 194,130	SERI
FY 80	$ 75,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY

The objective of this effort is to review potential supply, production and economic constraints of material technologies supported by the AR&D program including sensitivity and analysis of technology maturity, commercialization scenarios, and key material supply and production factors. Device technology manufacturing processes are characterized in terms of material requirements. A deployment scenario is postulated to calculate materials demand over time and compare against set criteria (resources, import fractions, capacity growth rates, cost, etc.) for potential supply problems. Results are analyzed and detailed investigations are recommended as needed.

A report has been published, The Evaluation of Critical Materials for Five Advanced Design PV Cells with an Assessment of Gallium and Indium, R. L. Watts et al., PNL-3319, May 1980 covering work performed with FY79 funds, and is available from NTIS. The five cells examined were polycrystalline silicon, amorphous silicon, cadmium sulfide/copper sulfide, polycrystalline gallium arsenide and an advanced III-V multijunction concentrator. Five additional technologies are presently under investigation. These are indium phosphide/cadmium sulfide, cadmium telluride, zinc phosphide, cadmium sulfide/copper indium selenide and a photoelectrochemical device, cadmium (telluride) selenide.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE Photovoltaics: Spectral Response of Solar Cells
CONTRACT NUMBER DZ-0-9235-1

CONTRACTOR (NAME AND ADDRESS):
Battelle Pacific Northwest Laboratory
PO Box 999
Richland, WA 99352

TELEPHONE (509)375-2101
PRINCIPAL INVESTIGATOR Dr. J. Hartman

DIRECTING ORGANIZATION AND ADDRESS:
SERI
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303)231-1361
PROJECT ENGINEER: Philip R. Pierce

CURRENT CONTRACT PERIOD:
FROM 9/80 TO: 9/81

PROBABLE PROJECT COMPLETION DATE 9/82

AREA/TASK
Technical Support/Measurement and Evaluation

CONTRACT FUNDING:

FY	$	SOURCE:
80	170,000	SERI

SUMMARY

The purpose of this effort is to examine problems associated with the reliable evaluation of photovoltaic cell response of advanced, thin film photovoltaic solar cells with the ultimate goal of developing a standardized PV energy conversion efficiency measurement technique that does not require the use of representative production lot standard solar cells.

Battelle will form a technical committee to review technical approach to problem and to serve in an advisory capacity for the duration of the program. The technical committee shall be comprised of experts from various PV material and device categories who are familiar with the problems associated with the technical effort. The candidates proposed for the technical committee shall be first reviewed and approved by SERI prior to formalization of the committee. At least one member of the SERI technical staff shall be a member of the technical committee.

Battelle will also perform examinations of experimental solar cells provided by SERI and other cooperating SERI Subcontractors to assess the technical problems examined in item one (1) above.

A detailed program plan summarizing the technical problems, the methodology designed to resolve the problems and progress toward an ultimate solution will be written. The program plan shall be prepared by the end of the first contract quarter for review and approval by SERI. The technical committee shall act as an advisor in the program plan approval process.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Cadmium Sulfide/Copper Selenide Cell Research

CONTRACT NUMBER: XG-0-9216-1

CONTRACTOR (NAME AND ADDRESS):
Boeing Aerospace Company
Electronics Technology
P. O. Box 3999
Seattle, WA 98124

TELEPHONE: (206) 773-1074

PRINCIPAL INVESTIGATOR: Reid Mickelson

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383

PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:

FROM: 6/1/80 **TO:** 5/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

		SOURCE:
FY 79	\$ 77,869	SERI
FY 80	\$ 77,581	SERI
FY	\$	
FY	\$	
FY	\$	

SUMMARY:

The purpose of this program is to continue investigation of the feasibility of using $Cu_{2-x}Se$ as a semiconductor material for the low cost production of photovoltaic solar cells. These cells would be formed as heterojunctions with CdS films. Both the selenide and sulfide films are deposited by vacuum evaporation methods onto inexpensive substrates which could lead to the possibility of large scale, low-cost cell production. The optical, electrical and structural properties of $Cu_{2-x}Se$ have been analyzed and found consistent with development of 10% efficient thin-film cells.

To meet the described objectives, research efforts are concentrating on the following:

1. Continuation of the development and characterization of controllably doped evaporated p-type $Cu_{2-x}Se$ films;

2. Continuation of the development and characterization of low resistance ohmic contacts to p-type evaporated $Cu_{2-x}Se$ films;

3. Development and characterization of greater than 1 cm^2 thin film evaporated $CdS/Cu_{2-x}Se$ heterojunctions with analysis of the mechanisms which control the photocurrent and junction rectification and limit the photovoltaic efficiency; and

4. Preliminary assessment of the stability of $CdS/Cu_{2-x}Se$ devices.

Improved control during film growth has allowed lower substrate temperatures (~ 160°C). In addition, by using a higher CdS source, CdS film resistivities down to 3 ohm-cm have been achieved. CdS/Cu_2Se solar cells have been fabricated with 1 cm^2 total area efficiencies of 3.3%, $V_{OC} = 0.45V$, $J_{SC} = 11.6\ mA/cm^2$ and $FF = 0.62$.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Cadmium Sulfide/Copper Ternary
CONTRACT NUMBER: XJ-9-8021-1

CONTRACTOR (NAME AND ADDRESS):
Boeing Aerospace Company
P. O. Box 3999 M/S 88-43
Seattle, WA 98124

TELEPHONE: (206) 773-1074
PRINCIPAL INVESTIGATOR: Reid Mickelsen

DIRECTING ORGANIZATION AND ADDRESS:
SERI/Photovoltaics Program Office
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 6/28/80 TO: 6/27/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/ Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
76	177,500	ERDA
78	177,000	DOE
79	255,000	SERI
80	256,500	SERI

SUMMARY

The objective of this program is to conduct research leading to the development of a large area, low cost, stable, polycrystalline thin-film photovoltaic solar cell of 10% efficiency based upon the CdS/$CuInSe_2$ material system. The technical approach is to improve performance and fabrication economics of earlier developed cells produced by vacuum evaporation techniques (simultaneous elemental evaporation for $CuInSe_2$) onto inexpensive substrates. Specific research tasks include: 1) improving cell performance by optimizing deposition process, grid geometry, and AR(anti-reflection) coating; 2) developing a cell model based on experimental analysis of cell parameters; 3) exploring the effects of alternate structures involving (Cd, Zn) S and Cd(S, Se); 4) study the effects of heat treatment; 5) initiating a stability study; 6) designing and implementing a large area cell fabrication process.

To date, cells with efficiencies between 9 - 9.5% with an AR coating have been fabricated on a repeatable basis. Effects of heat treatment ambients have been established. Short circuit current increased independent of ambient while open circuit voltage and fill factor requires the presence of oxygen for improvements. Uncoated cells exposed to room environments for one year showed no signs of significant degradation.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Advanced Amorphous Materials for Photovoltaic Conversion
CONTRACT NUMBER: DS-0-9055-1

CONTRACTOR (NAME AND ADDRESS):
Brookhaven National Laboratory
Dept. of Energy and Environment
Upton, Long Island, New York 11973

TELEPHONE: (516) 345-3544
PRINCIPAL INVESTIGATOR: Dr. Richard Griffith

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1483
TELEPHONE: (303) 231-1483
PROJECT ENGINEER: E. Sabisky

CURRENT CONTRACT PERIOD:
FROM: Oct. 1, 1980 **TO:** Sept. 30, 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 80	$266,000	SERI
FY 81	$346,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this project is to investigate new amorphous semiconductor (a-SC) materials, in which recombination centers are passivated, using plasma deposition techniques. The materials characterization emphasizes the optoelectronic properties pertaining to both majority-carrier and minority carrier transport in as-deposited films and in devices.

The technical approach in this project consists of the following tasks:

A. The growth of passivated a-SC films by glow-discharge decomposition of hydrides and/or halides. Elements of this task include: i) the study of plasma processing parameters; ii) the effects and sources of impurities such as nitrogen and oxygen; and iii) studies of the plasma chemistry by optical emission spectroscopy and other methods.

B. Characterization of as-deposited films, e.g., by measurements of photoconductivity, photoluminescence, visible and infrared optical absorption, thermopower, etc.

C. Fabrication and analysis of diagnostic devices such as MIS and p-i-n structures. Illuminated and dark I-V characteristics. hence the efficiencies, are obtained. Spectral response measurements are made in the presence of a white light bias.

The electronic properties of plasma-deposited a-Si:H films were found to depend strongly upon the incorporation of oxygen and nitrogen impurities. Electronic doping with nitrogen was achieved. From measurements on a series of Pd Schottky devices, the solar cell efficiency (in particular, the short-circuit current) was found to depend sensitively upon the degree of atmospheric impurity incorporation in a-Si:H alloys. A re-examination has resulted in the definition of "intrinsic" a-Si:H material produced by glow-discharge decomposition. Unusually high doping efficiency with PH_3 was found for a-Si:H alloys; e.g., 150 ppm PH_3 in silane yielded high conductivity $\sigma_d(300\ K) = 10^{-2}\ (\Omega cm)^{-1}$. Optical emission spectroscopy was used to identify and quantify emitting reactive species in the plasma (including important impurities).

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE:	Electrochemical Photovoltaic Cells
CONTRACT NUMBER:	XS-9-8312-1 -MOD I

CONTRACTOR (NAME AND ADDRESS):	DIRECTING ORGANIZATION AND ADDRESS:
Brooklyn College of CUNY Bedford Avenue and Avenue H Brooklyn, New York 11210	Solar Energy Research Institute 1617 Cole Boulevard Golden, CO 80401
TELEPHONE: (212) 780-5357	TELEPHONE: (303) 231-1369
PRINCIPAL INVESTIGATOR: Dr. Micha Tomkiewicz	PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 10/1/80 TO: 6/30/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/ Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
79	152,628	SERI
80	134,177	SERI

SUMMARY:

The objective of this contract is to characterize and develop high efficiency polycrystalline n-CdSe electrochemical photovoltaic cell devices incorporating aqueous electrolytes and to develop three electrode photoelectrochemical storage cells based on CdSe photoanodes.

The approaches which will be used are:

A. Grow polycrystalline thin films of n-type CdSe on metal substrates using the electrodeposition technique.

B. Characterize the electrodeposited CdSe films using electrolyte-electroreflectance spectroscopy and network analysis techniques.

C. Further characterize CdSe films as photoanodes in electrochemical photovoltaic cells.

D. Develop high efficiency electrochemical photovoltaic devices through improvements in the CdSe film quality and improvements in device configuration.

E. Design and construct three electrode storage cells using thin film CdSe photoanodes and exploring the use of various membrane and storage electrode candidates.

Brooklyn College has currently constructed experimental thin film CdSe electrochemical photovoltaic cells exhibiting over 6% efficiency using a $S/S^{-2}/OH^-$ aqueous electrolyte and Ni counterelectrodes. Electrodeposited CdSe films have been characterized using electrolyte-electroreflectance spectroscopy and impedance measurements. Various membranes as candidates for the three electrode storage cell have been characterized and new storage electrode systems are in the process of being developed.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Cadmium Sulfide/Mixed Copper Ternary Semiconductor Heterojunction Solar Cell Research

CONTRACT NUMBER: XI-9-8012-1

CONTRACTOR (NAME AND ADDRESS):

Brown University
Division of Engineering
Providence, RI 02912

TELEPHONE: (401) 863-2761

PRINCIPAL INVESTIGATOR: J. J. Loferski

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 10/79 **TO:** 3/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE
77	224,000	SERI
78	240,000	SERI
79	93,000	SERI
80	340,000 (approx)	SERI

SUMMARY:

The objectives of the research are to develop cadmium sulfide/copper ternary heterojunction solar cells which can be manufactured reproducibly with air mass-1 conversion efficiency of no less than 8% as measured between 20°C and 30°C over cell areas of at least 4 cm^2. Maximum electrical output degradation is to be 5% over twenty years.

The proposed continuation includes the following tasks: (1) fabrication of thin film cells by evaporation and sputtering using selected materials of ternary, quaternary, and pentenary combinations of Cu, In, Se, Te, Ag, Ga, and Al; (2) material diagnostics and characterization; (3) device modeling; (4) system modeling, and (5) fabrication and delivery of representative cells.

Professor Loferski and his colleagues have identified several potential candidates of materials which provide a perfect lattice match to CdS with proper bandgap. They have succeeded in preparing target materials from which thin film cells are to be fabricated either by evaporation or sputtering and up to 5% efficiency has been demonstrated. A small area cell fabricated from evaporated CdS film on sintered $CuIn_{.3}Ga_{.7}Se_{1.2}Te_{.8}$ has shown 13% conversion efficiency. The effort is now concentrated on the fabrication of a thin film and polycrystalline cell of this type of material.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Modelling, Analysis and Fabrication of SIS Solar Cells

CONTRACT NUMBER: XS-9-8233-1

CONTRACTOR (NAME AND ADDRESS):

Brown University
Division of Engineering
Providence, RI 02912

TELEPHONE: (401) 863-2761

PRINCIPAL INVESTIGATOR: John Schewchun

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1371

PROJECT ENGINEER: Thomas Surek

CURRENT CONTRACT PERIOD:

FROM: 10/1/78 TO: 4/30/80

PROBABLE PROJECT COMPLETION DATE: 4/30/80

AREA/TASK: Advanced Silicon/ Polycrystalline Silicon

CONTRACT FUNDING:		SOURCE:
FY 79	$ 145,588	SERI
FY 80	$ 33,316	SERI
FY	$	
FY	$	
FY	$	

SUMMARY

The objectives of this work are to extend the semiconductor-insulator-semiconductor (SIS) computer model to include effects of polycrystalline silicon on cell performance and detailed analyses of loss mechanisms in the SIS solar cells, and to optimize metallization technique and interfacial layer to obtain high efficiency solar cells.

The approach consists of: (1) determination of the electronic transport mechanisms in the SIS device to identify loss mechanisms and predict practical efficiencies; (2) identification of grain boundary effects on cell performance; (3) identification of long term stability; (4) optimization of the fabrication techniques; and (5) development of a theoretical model to determine the effects of non-stoichiometric interfacial insulating oxide.

Computer models of polycrystalline ITO-Silicon solar cells have been refined. The model utilizes the fact that a p/n junction is induced in the surface region of p-silicon by the ITO-silicon dioxide thin films. The effect of polycrystalline grains is incorporated by assuming that the grain and its boundary increase the concentration of recombination centers in the cell and thus reduce the effective lifetimes and diffusion lengths appearing in the equations from which the photovoltaic parameters (J_{sc}, J_o, V_{oc}, FF and η) are calculated. It is found that whereas the slopes of plots of J_{sc} and V_{oc} vs. grain size are in good agreement their magnitudes are not; the observed values are lower than theoretically predicted values. Calculations have been performed, as a function of grain size, of cell performance parameters obtainable from polycrystalline cells which include minority carrier mirrors and optical mirrors. The main conclusion of this work is that efficiencies between 15 and 22% should be reachable with grain sizes of about 50 μm and film thickness of about 50 μm. Experiments aimed at optimizing the performance of both single crystal and polycrystalline ITO-silicon dioxide-p-silicon solar cells have been carried out. The best AM1 efficiency obtained on a single crystal cell with 1.2 cm^2 active area was 16%, or 14% based on its total area of 1.35 cm^2. The best AM1 efficiency obtained on a cell fabricated on a Wacker polycrystalline silicon wafer was 9.6% based on a total area of 2.6 cm^2 and 11.2% based on an active area of 2.2 cm^2.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Efficient Luminescent Solar Concentrators
CONTRACT NUMBER: XS-9-8177-1

CONTRACTOR (NAME AND ADDRESS):
California Institute of Technology
Pasadena, California 91103

TELEPHONE: (213) 795-6811 x2537
PRINCIPAL INVESTIGATOR: Ahmed Zewail

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1311
PROJECT ENGINEER: Allen Hermann

CURRENT CONTRACT PERIOD:
FROM: 5/15/79 **TO:** 5/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Photovoltaic Compound Semiconductors/ Innovative Concepts

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 144,116	
FY 80	$ 163764	
FY	$	
FY	$	
FY	$	

SUMMARY:

The ultimate objective of this research is to produce high efficiency (> 8%) Luminescent Solar Concentrators. Specific areas to be investigated include energy transfer between dye ensembles, relaxation for excitation within the same dye ensemble, Stokes-shift characterization to minimize self-absorption, and theoretical limiting efficiency studies from a thermodynamic standpoint.

Six tasks have been identified:

a) Survey of the physical characteristics of the constituents used in LSC devices.
b) Study of inter-dye ensemble energy transfer rates in the steady-state as a function of dye concentration.
c) Measurement of relaxation times for dyes using a passively mode-locked pulse laser.
d) Observation of intra-dye energy exchange rates as a function of excitation energy and matrix material temperature.
e) Building of several concentrators of novel design, consisting of dyes in solution between two glass plates.
f) Study of photodegradation rates of dyes in a variety of hosts.

A computer data acquisition system has been interfaced with two automated spectrometers allowing routine gathering and storage of emission and excitation spectra of dye molecules. Multi-dye systems have been studied using this set-up. Concentration dependences have shown that at low concentrations (less than .0005 molar) energy transfer between ensembles does not compete successfully with simple fluorescences. Dye relaxation times have also been measured and the "freezing" of rotational relaxation in rigid media has been observed. Directional properties of transition moments in the dye molecules have also been studied. Self-absorption has been shown to be a dominant effect and its impact has been shown to be predicted reasonably well from the theoretical formalism developed. Liquid hosts have been investigated, and dye lifetimes have been measured to be anomolously long. Half-lives approaching 100 days have been established in actual outdoor weathering tests.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Grain Growth in Polycrystalline Silicon
CONTRACT NUMBER: HS-0-9112-1

CONTRACTOR (NAME AND ADDRESS):

(Department of Metallurgy)
Case Western Reserve University
Cleveland, OH 44106
TELEPHONE: (216) 268-4236
PRINCIPAL INVESTIGATOR: G. E. Welsch

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1371
PROJECT ENGINEER: Thomas Surek

CURRENT CONTRACT PERIOD:
FROM: 1/80 TO: 10/80

PROBABLE PROJECT COMPLETION DATE: 10/80

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 24,800	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this investigation is to gain information on grain growth of polycrystalline silicon in recrystallization heat treatments.

The approach to the research is to use a fine grained (0.1 to 1 μm) starting material which had been produced by sintering of amorphous silicon powder, and to subject it to recrystallization heat treatments just below the melting temperature (T_m) of silicon.

The studies to date have demonstrated that recrystallization heat treatments at 1380°C (T_m= 1410°C) produced negligibly small grain growth even after times as long as 100 min. The resulting grain size, as measured from TEM micrographs, was 0.2 to 1 μm. However, the density of twin boundaries within the grains was substantially reduced by the high temperature heat treatment. The reasons for the non-recrystallization behavior are not yet understood.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Future Supply of Gallium CONTRACT NUMBER: XS-9-8258-1	
CONTRACTOR (NAME AND ADDRESS): Charles River Associates, Incorporated 200 Clarendon Street Boston, MA 02116 TELEPHONE: (617) 266-0500 PRINCIPAL INVESTIGATOR: F.E. Katrak	DIRECTING ORGANIZATION AND ADDRESS: PV Analysis and Evaluation Branch Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401 TELEPHONE: (303) 231-1392 FTS 327-1392 PROJECT ENGINEER: S.R. Nagy
CURRENT CONTRACT PERIOD: FROM: 8/14/80 TO: 7/11/80	CONTRACT FUNDING: SOURCE: FY 79 $ 61,449 SERI FY ___ $ ___ ___ FY ___ $ ___ ___ FY ___ $ ___ ___ FY ___ $ ___ ___
PROBABLE PROJECT COMPLETION DATE: completed	
AREA/TASK: Technical Support/Availability of Materials	

SUMMARY

The objective of this effort was to estimate the long-run supply of gallium between 1990 and 2020. The supply price of gallium was assessed as a function of demand scenarios and rates of introduction of gallium arsenide photovoltaic systems. Gallium supply was delimited by identifying all resources from which gallium might be recovered economically in significant amounts. Current recovery processes were evaluated and some new ones designed. Non-photovoltaic gallium demands, possible coproducts of gallium recovery, overall market structure and potential bottlenecks, constraints, and supply disruptions were all evaluated. The report, Gallium: Long-Run Supply, CRA report #483, June 1980 details the above and is available from Charles River Associates, Inc.

BEST DOCUMENT AVAILABLE

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: A Proposal on a Commercial Photoelectrochemical Device

CONTRACT NUMBER: XP-9-8002-5-MOD I

CONTRACTOR (NAME AND ADDRESS):

Chronar
P. O. Box 177
Princeton, NJ 08540
TELEPHONE: (609) 587-8000
PRINCIPAL INVESTIGATOR: Dr. Zoltan Kiss

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
FTS-327-1369
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 5/15/80 TO: 5/14/81

PROBABLE PROJECT COMPLETION DATE: 5/14/81

AREA/TASK: Compound Semiconductor/ Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
79	137,154	SERI
80	170,087	SERI

SUMMARY:

The overall objective of this program is to acquire a reliable technological know-how, using simple and cost-effective methods and inexpensive materials, for the production of commercially viable thin-film photoelectrochemical (PEC) solar cells.

A total system approach has been taken with four major tasks:

1) preparation of cadmium chalcogenide photoelectrodes using chemical spraying deposition (CSD) and electrodeposition (ED) techniques.
2) preparation of metal chalcogenides counter-electrodes on metal or electroless Cu deposited glass substrates.
3) optimization of chalcogenide/polychalcogenide solution and exploring gel type electrolyte.
4) developing a low permeability plastic seal all glass cell.

Cadmium chalcogenide and mixed chalcogenide photoelectrodes have been prepared to date by CSD and ED techniques with solar power efficiency from 1 to 3% in polysulfide electrolyte. A sealed CdSe/polysulfide PEC solar cell has been demonstrated.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Investigation of Efficiency Loss Mechanisms in CdS/Cu_2S and Related Thin Film Solar Cells

CONTRACT NUMBER: XZ-0-9211

CONTRACTOR (NAME AND ADDRESS):
Clarkson College of Technology
Electrical Engineering Department
Potsdam, New York 13676

TELEPHONE: (315) 268-2349
PRINCIPAL INVESTIGATOR: N. K. Annamalai

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 7/1/80 **TO:** 6/30/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Cadmium Sulfide

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 99,675	SERI
FY 80	$ 87,293	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this project is to obtain a better understanding of those mechanisms which cause efficiency losses in polycrystalline, thin-film CdS/Cu_2S and related solar cells. Special attention is being placed on two specific mechanisms, these being oxidation and interdissusion.

To meet the desired objective, four tasks have been identified:

1. Investigate oxidation and the interdiffusion of Cu and Cd in CdS/Cu_xS solar cells, and their relation to efficiency and stability of cell performance.
2. Produce CdS/Cu_xS cells (with x being near 1.995) by sequential evaporation of the two constituent active layers without breaking the vacuum.
3. Characterize films and cells produced by (a) evaporation, and (b) the conventional wet-dip process. These will be compared, especially with regard to Cu oxidation and interdiffusion. Various measurement techniques will be used including capacitance, resistivity, I-V data, Hall effect, spectral response and ion-scattering spectroscopy.
4. Perform accelerated degradation experiments and relate data to Cu oxidation and to interdiffusion identified by characterization and performance data.

Cells fabricated by the sequential evaporation process have demonstrated efficiencies between 1 and 2%. Interdiffusion of Cu and Cd have been observed by Auger spectroscopy studies on heat treated cells. Resistivity and Hall effect measurements have been made on heat treated Cu_xS films. Photoconductive decay in CdS films have been studied. Deep trap levels in CdS have been identified by capacitance versus voltage measurements on Cu_xS/CdS cells.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Fabricate, Characterize and Stabilize Silicon Semiconductor Solar Cells
CONTRACT NUMBER: XS-9-8232-1

CONTRACTOR (NAME AND ADDRESS):

Colorado State University
Electrical Engineering Department
Fort Collins, CO 80521
TELEPHONE: (303) 491-8235
PRINCIPAL INVESTIGATOR: Joel B. DuBow

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1371
PROJECT ENGINEER: Thomas Surek

CURRENT CONTRACT PERIOD:
FROM: 10/1/78 TO: 4/31/80

PROBABLE PROJECT COMPLETION DATE: 4/31/80

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
76	204,000	DOE/ERDA
77	277,577	DOE
79	280,000	SERI
80	46,612	SERI

SUMMARY:

The objectives of this effort are to develop high efficiency, large area ITO (or other conducting oxides)/insulator/silicon solar cells, and to analyze the physical mechanisms determining and limiting device performance in metal-insulator-semiconductor(MIS) and semiconductor-insulator-semiconductor (SIS) solar cells.

The technical approach consists of: (1) determination of fundamental physical mechanisms that control and limit the SIS cell performance; (2) fabrication of SIS solar cells; (3) characterization of interfacial insulating layer; (4) determination of long term stability; and (5) optimization of fabrication and treatment techniques.

The optimization of the fabrication sequence involves the following steps: improved substrate surface preparation, incorporation of hydrogen during milling, growth of an ultrathin interfacial layer, deposition of ITO (750A^0), and finally grid deposition. It is clear from the measurement of I-V, C-V and the spectral response that hydrogen passivation minimizes the static and dynamic effect of surface states located at the insulator-semiconductor interface. Initial results on Wacker and Monsanto material indicate that hydrogen is passivating surface defects and grain boundaries, mostly at the interface with some effect on the bulk properties of the material. Improved efficiency large area ITO-SiO_x-polysilicon solar cells have been achieved. On total area (11.46 cm^2) and active area (9.67 cm^2) basis, 11.5% and 13.6% efficient ITO/Wacker polysilicon cells have been fabricated. Similar results have been obtained for 18.64 cm^2 devices, with slightly lower efficiency due to nonoptimized grid pattern. The measured sheet resistivity of 750 A^0 ITO will enable further scaling of these devices to production size wafers (50-100 cm^2 devices). Preliminary results on highly defected polysilicon substrates, Honeywell silicon on ceramic (SOC) and Mobil Tyco ribbon material, are very encouraging. Efficiencies as high as 9.2% (active area = 1.17 cm^2) and 9.9% (active area = 3.7 cm^2) have been obtained for SOC and Tyco materials, respectively.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE Fundamental Studies of M-S and MIS Solar Cells on Polycrystalline Silicon
CONTRACT NUMBER RZ-0-9226-1

CONTRACTOR (NAME AND ADDRESS):
Columbia University
Dept. of Electrical Engineering
New York, NY 10027

TELEPHONE: (212) 280-3120
PRINCIPAL INVESTIGATOR: E. S. Yang

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1482
PROJECT ENGINEER: R. W. Hardy

CURRENT CONTRACT PERIOD:
FROM: 9/80 TO: 8/81

PROBABLE PROJECT COMPLETION DATE 8/81

AREA/TASK Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:		SOURCE:
FY 79	$ 232,311	DOE
FY 80	$ 154,658	SERI
FY	$	
FY	$	
FY	$	

SUMMARY

The purpose of this contract is to investigate the fundamental properties of M-S and MIS Schottky-Barrier solar cells fabricated on polycrystalline silicon substrates.

A new technique, in which the open-circuit voltage is plotted vs. short-circuit current at varying illumination intensity, is found to provide a better description of the solar cells when the n-value reflects the electrostatic potential drop across the interface layer in MIS structures. The majority carrier MIS cell (e.g., Au-SiO_2-nSi) has been found to be less sensitive to the parameters of the oxide layer, but to have a somewhat lower efficiency than the minority-carrier cell (e.g., Al-SiO_2-pSi). The tunneling barriers for the holes are found to be consistently much larger than those for electrons.

Experimental I-V and C-V characteristics of Schottky diodes with variable grain sizes have been measured. Analyses of the data indicate that the transport may be electrode-limited or bulk-limited depending on the average grain size. In addition, minority carrier injection dominates the dark current for sufficiently small grain size and large grain-boundary (GB) mismatch angle. The minority carrier current shows an exp (qV/nKT) dependence with n values of unity, of 2 or 4/3 depending upon the grain boundary barrier height and the region of applied bias voltage.

Al-poly-Si Schottky-barrier diodes have been fabricated on Wacker polycrystalline wafers. By examining the surface features of diodes on the same substrate, it was found that high-angle grain boundaries, distinguished by different etch pits on the two adjacent grains, have a strong influence on the current-voltage and low-frequency capacitance characteristics of the diode. On the other hand, twin boundaries, with similar etch pits on both sides of the boundary, have little effect on the current transport and capacitance with the exception that the Schottky-barrier height is consistently higher than the corresponding single-crystal diodes.

Finally, a technique was developed for forming Schottky barriers with high barrier height (0.93 eV) and low reverse saturation current (10^{-5} A/cm^2). This structure has the potential of high open-circuit voltage and efficiency.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Low-Cost Silicon Substrates by Directional Solidification	
CONTRACT NUMBER: XS-0-9171-1	
CONTRACTOR (NAME AND ADDRESS): Crystal Systems, Inc. 35 Congress Street Salem, MA 01970 TELEPHONE: (617) 745-0088 PRINCIPAL INVESTIGATOR: Chandra P. Khattak	DIRECTING ORGANIZATION AND ADDRESS: Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401 TELEPHONE: (303) 231-1379 PROJECT ENGINEER: Arie P. Ariotedjo
CURRENT CONTRACT PERIOD: FROM: 3/1/80 TO: 2/28/81	CONTRACT FUNDING: FY 79 $ 227,000 SOURCE: SERI FY ___ $ ___ ___ FY ___ $ ___ ___ FY ___ $ ___ ___ FY ___ $ ___ ___
PROBABLE PROJECT COMPLETION DATE: 2/28/81	
AREA/TASK: Advanced Silicon/ Polycrystalline Silicon	

SUMMARY:

The objective of this work is to identify and develop low-cost processes for fabricating large grain-size polycrystalline silicon substrates. Specifically, the studies will involve the directional solidification of silicon ingots using the Heat Exchanger Method (HEM). The investigations will examine the use of metallurgical grade (MG) silicon as the feedstock for the casting process, and will study both prior and in situ purifications to obtain high purity, low-cost polycrystalline silicon substrates.

All known suppliers of MG silicon have been contacted. The samples received have been analyzed by emission spectroscopic techniques. The commercially available silicon has been found to contain between 98 to 99% silicon. Single crystal structure in 15 cm cube ingots was produced by HEM from all sources of MG silicon tested. This is believed to be the first time a single crystal structure has been produced from MG silicon by a single directional solidification. The major contaminants existed as oxides and carbides which form particulates in molten silicon and generally float on the surface of the melt. After directional solidification most of the impurities, except for aluminum and iron, were reduced below the detectibility limits of spark source emission spectographic analysis. The resistivity of HEM solidified MG silicon was in the range of 0.03 to 0.08 Ω-cm. Epitaxial solar cells fabricated using this silicon substrate have shown AM1 conversion efficiencies up to 11.6%, about 90% of the control cells made from high-purity CZ silicon substrates.

Various refining operations, such as vacuum melting and slagging, have been carried out in the HEM furnace. The effect of holding time and superheat temperatures on the volatilization of high vapor pressure impurities has also been studied.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Preparation and Characterization of Hydrogenated a-Si Films Produced by Ion Plating and Hydrogenated a-B Films Produced by Glow Discharge Decomposition

CONTRACT NUMBER: XJ-0-9054-1

CONTRACTOR (NAME AND ADDRESS): Duke University Durham, N.C. 27706 TELEPHONE: (919) 684-2832 PRINCIPAL INVESTIGATOR: Drs Franklin Cocks & Phillips Jones	DIRECTING ORGANIZATION AND ADDRESS: SERI/PVAS 1617 Cole Blvd. Golden, CO 80401 TELEPHONE: (303) 231-7039 PROJECT ENGINEER: T. McMahon

CURRENT CONTRACT PERIOD:
FROM: 4/1/80 TO: 3/31/81

PROBABLE PROJECT COMPLETION DATE: 3/31/82

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	265,000	DOE
80	275,000	DOE
81	192,000	SERI

SUMMARY:

Ion plating techniques for the preparation of hydrogenated amorphous silicon thin films have been successfully developed. The technique involves essentially the evaporation of elemental silicon through a d.c. produced hydrogen plasma. In this way hydrogen has been successfully incorporated into amorphous silicon films in concentrations as high as 30 atomic percent. Infrared spectroscopy indicates the usual SiH_x stretching mode at approximately 2000 cm^{-1}. Further evidence for the bonding of hydrogen was obtained from ESR measurement of hydrogenated and unhydrogenated samples. The measured unpaired spin density was a factor of 25 less in the hydrogenated sample. The optical absorption edges of the hydrogenated films fell in the usual range between 1.7 and 1.9 eV. Electrical conductivity measurements indicated a substantial reduction in the density of defect states in the gap as expected. It was also shown that hydrogenated amorphous silicon prepared by ion-plating could be doped by co-evaporation of the dopant element during film deposition. Both co-evaporated phosphorous and co-evaporated bismuth have been found to substantially increase the dark conductivity of a-Si:H while shifting the Fermi level towards the conduction band edge.

Amorphous boron (a-B) films have been produced by glow discharge decomposition of diborane in a diborane-hydrogen plasma. The presence of hydrogen in the films in the range of 5% to 34% has been confirmed by residual gas analysis. The optical band gaps of these films can be varied from as much as 2.2 eV to 0.9 eV by vacuum annealing. Heating of the substrates during deposition of the films produced varying optical gaps. Evolution of incorporated hydrogen by these means is believed to lead to the lowering of the optical gap. Boron films produced from plasmas into which small amounts of silane and hydrogen were introduced showed lower activation energies for conduction than did the intrinsic a-B films. These lower activation energies suggest that silicon and carbon have been incorporated into the film and are acting as dopants.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: ELECTRODEPOSITION OF POLYCRYSTALLINE AND AMORPHOUS SILICON FOR PHOTOVOLTAIC APPLICATIONS

CONTRACT NUMBER: DE-AC03-79ET23046

CONTRACTOR (NAME AND ADDRESS):

EIC Laboratories, Inc.
55 Chapel Street
Newton, MA 02158

TELEPHONE: (617) 965-2710
PRINCIPAL INVESTIGATOR: R. David Rauh

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-7299
PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:
FROM: July 11, 1979 **TO:** September 10, 1980

PROBABLE PROJECT COMPLETION DATE: 9/10/80

AREA/TASK: ADVANCED SILICON/
POLYCRYSTALLINE SILICON

CONTRACT FUNDING:

		SOURCE:
FY 1980	$ 187,501	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this project is to evaluate the reactions and optimize conditions for electrodepositing films of both amorphous and polycrystalline silicon which can be used in solar cell fabrication. The program is designed to provide an understanding of the dependence of the physical, chemical, and electrical properties of the film on the electrodeposition conditions.

Amorphous silicon films are electrodeposited on conductive substrates at low temperatures ($< 100^{o}$C) from silicon precursors dissolved in organic solvents. Polycrystalline silicon is deposited using silicon salts dissolved in molten fluoride salts at temperatures above 700^{o}C. Both galvanostatic and potentiostatic plating conditions are employed. The adherence, resistivity, chemical purity, morphology and optical properties of the resulting films are characterized.

Electrodeposits of polycrystalline silicon were obtained on silver substrates from eutectic mixtures of LiF-KF and LiF-KF-NaF (FLINAK) using K_2SiF_6 as silicon precursor at temperatures $>800^{o}$C. Analysis by atomic emission and EDAX showed metallic impurities of less than 0.25 wt.% for the best samples. The morphology of the deposits was generally poor with needle bushes, small grain size and occluded salt. Extensive electrochemical analysis of the melt was used to monitor melt purity and deposition potentials. Plating efficiencies up to 90% were obtained by plating and stripping measurements. The plating potential was found to be very sensitive to impurities in the melt. Thin films (< 2 μm) of amorphous Si were electrodeposited on Mo, ITO, and polycrystalline silicon from solutions of propylene carbonate using $SiHCl_3$ and $SiHBr_3$ as silicon precursors. _In situ_ measurement of the resistivity of the films gave values of 10^{6}-10^{8} ohm-cm. SEM analysis of the films showed a porous morphology with nodules about 1 μm in diameter. The IR and Auger spectroscopy revealed high concentrations of oxygen in the samples which were not removed by annealing in an Ar-H atmosphere at 400^{o}C. The films deposited on ITO glass had a band gap of about 1.0 eV and an EO_4 value in the range of 1.5-2.0 eV.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Use of Inorganic Materials for Phosphorescent Concentrating Solar Collectors

CONTRACT NUMBER: XS-9-8041-13

CONTRACTOR (NAME AND ADDRESS):
EIC Corporation
55 Chapel Street
Newton, Massachusetts 02158

TELEPHONE: (617) 965-2710

PRINCIPAL INVESTIGATOR: Peter O'D. Offenhartz

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1311

PROJECT ENGINEER: Allen Hermann

CURRENT CONTRACT PERIOD:

FROM: 9/15/79 **TO:** 6/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Innovative Concepts

CONTRACT FUNDING:

FY	$	SOURCE:
79	83,044	SERI
80	63,625	SERI

SUMMARY:

The objective of this program is to prepare and characterize inorganic phosphorescent compounds suitable for use in luminescent solar concentrating collectors. Such materials should have extremely low reabsorption coefficients for luminescently emitted light, which should allow the development of large-area, single pane collectors with high concentration ratios.

Four tasks have been identified:

a. Compound selection, based on both theoretical (ligand field theory) and literature data.

b. Compound synthesis.

c. Compound compatibility with various matrix materials.

d. Spectroscopic characterization, including absorption and emission spectra and phosphorescent quantum yield. The results of spectroscopic characterization will be used in further compound selection and characterization.

An extensive literature review of octohedrally coordinated d^3 compounds has been completed. Seven compounds deemed promising have been synthesized. An apparatus for measurement of phosphorescent lifetimes and quantum yields has been constructed, and absorption spectra taken on all of the synthesized compounds. Emission spectra have been taken for one compound, and the remaining spectroscopic characterization is underway. Current efforts are aimed at optimizing the quantum yields of new and previously tested dye compounds.

Date: September 1980

SERI

Photovoltaic AR&D Lead Center

TITLE: Development of Photoelectrochemical Cells Based on Compound Semiconductors and Non-Aqueous Electrolytes
CONTRACT NUMBER: XP-9-8002-7 -MOD I

CONTRACTOR (NAME AND ADDRESS): EIC 55 Chapel Street Newton, Massachusetts 02158 **TELEPHONE:** (617) 965-2710 **PRINCIPAL INVESTIGATOR:** R. David Rauh	**DIRECTING ORGANIZATION AND ADDRESS:** Solar Energy Research Institute 1617 Cole Boulevard Golden, CO 80401 **TELEPHONE:** (303) 231-1369 **PROJECT ENGINEER:** Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 5/1/80 **TO:** 4/30/81

PROBABLE PROJECT COMPLETION DATE: 4/30/81

AREA/TASK: Compound Semiconductor/ Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
79	198,275	SERI
80	160,909	SERI

SUMMARY:

The objective of this project is to produce a family of exceedingly stable and efficient photoelectrochemical solar cells based on compound semiconductors and nonaqueous solvents.

During the second year of this program, research efforts are focused on GaAs, CdSe, and Zn_3P_2. The mixed compound semiconductor $CdSe_xTe_{1-x}$ will also be examined. For these photoelectrodes, the factors controlling stability, photovoltage, and photocurrent in nonaqueous solvents will be identified. The photoelectrodes will be characterized as single crystals and polycrystalline films. Screen printing and electrodeposition will be used to prepare thin film materials.

EIC has investigated a number of nonaqueous solvent-redox couple systems during the first year of this work and has decided to focus now on four redox couple systems in acetonitrite for GaAs and cadmium chalcogenide semiconductor photoanodes. Preliminary experiments in aqueous electrolytes have been carried out to characterize p-Zn_3P_2. Several new device configurations for electrochemical photovoltaic cells have been conceived and are in the process of being executed for promising systems. Experiments are proceeding on very large area photoelectrode systems suitable for electrodeposited thin film materials.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Preparation and Characterization of Amorphous $ZnAs_2$ for Use in Solar Cells

CONTRACT NUMBER: XZ-0-9243

CONTRACTOR (NAME AND ADDRESS):
EIC Corporation
55 Chapel Street
Newton, Massachusetts 02158
TELEPHONE: (617) 965-2710
PRINCIPAL INVESTIGATOR: R. David Rauh

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute/PVAS
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1373
TELEPHONE: (303) 231-1370
PROJECT ENGINEER: Jack Stone

CURRENT CONTRACT PERIOD:
FROM: 7/15/80 **TO:** 1/14/81

PROBABLE PROJECT COMPLETION DATE: 1/14/81

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	86,400	DOE
81	43,942	SERI

SUMMARY:

The objective of this project is to evaluate the potential of the $A^{II}B^{IV}C_2^{V}$ tetrahedral glasses as solar cell materials.

The research is directed towards four principal tasks to meet this objective:

1. Synthesis and characterization of bulk quantities of $A^{II}B^{IV}C_2^{V}$ compounds.
2. Production of amorphous thin films of these materials.
3. Evaluation of optical and electrical properties of the amorphous materials.
4. Construction and testing of solar cells.

The series of $ZnMAs_2$ and $CdMAs_2$ where M = Si, Ge, Sn were made by fusion of the elements. Preparation of the corresponding phosphides was not successful. Thermal evaporation of the ternary compounds to produce thin films resulted in film stoichiometry deficient in the Group IV element. Thin films of amorphous $ZnAs_2$, however, have been prepared with good stoichiometries. The structural, electrical and optical properties of the a-$ZnAs_2$ films are being characterized.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Low Angle Silicon Sheet (LASS) Process
CONTRACT NUMBER: XS-9-8041-3

CONTRACTOR (NAME AND ADDRESS):

Energy Materials Corporation
Ayer Road, P.O. Box 353
Harvard, MA 01451

TELEPHONE: (617) 456-8707
PRINCIPAL INVESTIGATOR: D. N. Jewett

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1379
PROJECT ENGINEER: Arie P. Ariotedjo

CURRENT CONTRACT PERIOD:
FROM: 9/79 **TO:** 6/81

PROBABLE PROJECT COMPLETION DATE: 6/81

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	99,661	SERI
80	200,000	SERI

SUMMARY:

The objective of this program is to develop a high productivity ribbon/sheet growth technique which will produce silicon ribbon/sheet suitable for fabricating greater than 10% AM1 efficiency solar cells. The Low Angle Silicon Sheet (LASS) growth technique, an extension of horizontal ribbon growth technique, has the low-cost potential of producing silicon ribbon/sheet with volume productivity similar to that of Czochralski crystal growth.

The approach consists of: (1) LASS process optimization; (2) LASS process scale up; and (3) solar cell fabrication.

Substantial progress in meeting the objective has been demonstrated; high speed ribbon growth of 85 cm/min has been achieved. Ribbons are typically 1 cm wide x 0.025 inch thick x 50 cm long, with grain width of 4mm.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Investigation of Materials for Liquid Supported Horizontal Growth of Silicon

CONTRACT NUMBER: HZ-0-9288-1

CONTRACTOR (NAME AND ADDRESS):

Energy Materials Corporation
Ayer Road, P. O. Box 353
Harvard, MA 04151

TELEPHONE: (617) 456-8707

PRINCIPAL INVESTIGATOR: David N. Jewett

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1379

PROJECT ENGINEER: A. P. Ariotedjo

CURRENT CONTRACT PERIOD:

FROM: 7/80 **TO:** 10/80

PROBABLE PROJECT COMPLETION DATE: 10/80

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	24,893	SERI
~~80~~	~~24,640~~	~~SERI~~

SUMMARY:

The objective of this program is to explore a variation of horizontal silicon ribbon growth which uses a refractory liquid to support the silicon as it is being solidified. Such liquid should not react with the silicon liquid or solid. The advantage of this approach is that the thickness of the ribbon is controlled by the balance of liquid silicon feed and the rate of ribbon withdrawal; the thickness is controlled independently from the pull rate, solidification rate and geometry, or thermal gradients. In addition, the growth process is easy to initiate and the shape of the solidification gradient is continuously controlled without stopping the ribbon growth.

The main effort of this program is the selection of the appropriate supporting liquid. Several fluoride salts have been shown to hold promise. A crystal growth set up has been designed and constructed to test the horizontal ribbon growth. Some of the likely liquid salt candidates are barium fluoride, ytterbium fluoride, and holmium fluoride.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE:

CONTRACT NUMBER:

CONTRACTOR (NAME AND ADDRESS):
Exxon Research and Engineering Company
P. O. Box 8
Linden, NJ 07036

TELEPHONE: (201) 474-0100

PRINCIPAL INVESTIGATOR: Joseph Sansregret

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383

PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:

FROM: 9/24/79 TO: 9/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	84,363	SERI

SUMMARY:

The study addresses an exploratory development program wherein a new photovoltaic material, $ZnSnP_2$, will be deposited by the ion exchange chemical spray deposition (CSD) technique. The objective of this program is to evaluate $ZnSnP_2$, a potentially high efficiency photovoltaic semiconductor, and to concurrently develop a deposition method for $ZnSnP_2$ particularly to identify a new low cost thin film solar cell alternative. The program goal is to determine the potential of $ZnSnP_2$ to yield high efficiency solar cells fabricated by the ion exchange CSD method.

Crystalline $ZnSnP_2$ thin films have been successfully grown by a modified ion-exchange-CSD process and characterized by x-ray diffraction from x-ray data, good agreement is found for the observed and calculated interplanar spacings. Preliminary optical data on our crystalline $ZnSnP_2$ films indicate a direct bandgap of ca. 1.5eV.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Thin Film Polycrystalline Silicon Solar Cells
CONTRACT NUMBER: XJ-0-9077-1

CONTRACTOR (NAME AND ADDRESS):
Exxon Research and Engineering Co.
P. O. Box 45
Linden, NJ 07036
TELEPHONE: (201) 474-3465
PRINCIPAL INVESTIGATOR: A.K. Ghosh

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1482
PROJECT ENGINEER: R.W. Hardy

CURRENT CONTRACT PERIOD:
FROM: 5/80 TO: 4/81

PROBABLE PROJECT COMPLETION DATE: 4/81

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
76	245,837	ERDA
79	272,000	DOE
80	250,000	SERI

SUMMARY:

The primary objectives of the contract are: 1) to improve the spray deposition processes to further define the maximum capabilities of the SnO_2/n-Si and ITO/n-Si heterojunction solar cells; 2) to assess the stability of such cell structures; 3) to understand the effects of grain boundaries on the electrical and photovoltaic properties of polycrystalline silicon; and 4) to determine the feasibility of a large-scale fabrication process.

In order to fulfill the above stated objectives, SnO_2/n-Si and ITO/n-Si cells are fabricated on single and polycrystalline materials by utilizing the spray deposition technique. The effects of grain size on cell efficiency are studied by fabricating hetero-and homo-junction solar cells on different types and grain-size polycrystalline silicon materials. To assess the stability of the various cell structures, detailed degradation tests are carried out. Various measurement techniques have also been developed to analyze the device performance and fundamental mechanisms that could limit cell efficiency.

Power conversion efficiencies (total area) of 13.7% and 11.2% have been achieved on single and polycrystalline silicon, respectively, utilizing the spray deposition process for fabricating heterojunction cells. Diffused homojunction (p on n) polysilicon cells having 10.3% efficiency were also made. Long term stability tests of encapsulated SnO_2/n-Si are being carried out in an outdoor test facility in sunlight. These cells become stable after a small initial drop in the open circuit photovoltage. The effects of grain size on the Hall measurements in polycrystalline silicon have been analyzed and interpreted on the basis of a model that assumes the measured effective Hall voltage is composed of components originating from the bulk and from the space-charge regions. The predictions of such a model are consistent with the experimental results of mm-size Wacker and μm-size neutron-transmutation-doped (NTD) polysilicon materials.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Spray Solar Cell Research
CONTRACT NUMBER: XS-9-8104-1

CONTRACTOR (NAME AND ADDRESS):
Exxon Research and Engineering Company
P. O. Box 8
Linden, NJ 07036

TELEPHONE: (201) 474-2054
PRINCIPAL INVESTIGATOR: H. Paul Maruska

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 9/80 **TO:** 3/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
79	191,000	SERI
80	95,000	SERI

SUMMARY:

The objective of this project is the development of a spray fabrication process for thin film Cu_2S/CdS solar cells with an engineering efficiency goal of 8% AM1. The methods for fabricating high efficiency CdS/Cu_2S solar cells, which will utilize a recently developed chemical spray deposition - ion exchange process. The technique involves using the spray deposition method for depositing starting oxide films, followed by an ion-exchange process for converting the oxides to sulfides.

The program will be involved both with characterizing the optical, electrical and structural properties of the deposited films and with evaluating the performances of completed devices. The studies will include several device configurations, including both frontwall and backwall cells.

To date the CdO spray and CdS conversion process have been established. The CdS films have been characterized in terms of optical transmission, electrical resistivity, photoluminescence measurements. Cu_2S/CdS cells have been formed and characterized.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Sputtered Amorphous Silicon Solar Cells

CONTRACT NUMBER: XZ-0-9219

CONTRACTOR (NAME AND ADDRESS):
Exxon Research and Engineering Co
P.O. box 8
Linden, N.J. 07036

TELEPHONE: (201) 474-2051

PRINCIPAL INVESTIGATOR: Ted Moustakas (Dr.)

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7039

PROJECT ENGINEER: T. McMahon

CURRENT CONTRACT PERIOD:

FROM: Oct 1980 **TO:** Oct 1981

PROBABLE PROJECT COMPLETION DATE: Oct 82

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
81	275,000	SERI

SUMMARY:

Progress over the past two years in the preparation and characterization of sputtered hydrogenated amorphous silicon has led to solar cell structures with efficiencies approaching those fabricated by decomposition of silane. Based on this rapid progress, it is clear that sputtering should be considered as an equal partner to glow discharge deposition in terms of process control, and it is anticipated that the development of a prototype solar cell at the laboratory level could be transferred to a mass production scheme much more rapidly than for a similar glow discharge development.

Deposition of a-SiH_x films will be by RF, DC and Magnetron sputtering. This will allow the relative merits of the three basic sputtering techniques to be evaluated and the one producing films with the most promising photovoltaic properties to be chosen. The achievement of a solar cell structure with 1 cm^2 area having an efficiency of 4% is considered likely. This would be the first step in a development program leading to a 10% device.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Feasibility Study of a Six-Point Probe Method
CONTRACT NUMBER: HZ-0-9176-1

CONTRACTOR (NAME AND ADDRESS):
Four Dimensions Inc.
PO Box 3365
San Mateo, CA 94403
TELEPHONE: (415)574-0266
PRINCIPAL INVESTIGATOR: Dr. J. T. C. Chen

DIRECTING ORGANIZATION AND ADDRESS:
SERI
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303)231-1361
PROJECT ENGINEER: Philip R. Pierce

CURRENT CONTRACT PERIOD:
FROM: 5/80 TO: 5/81

PROBABLE PROJECT COMPLETION DATE: 5/81

AREA/TASK:
Technical Support/Measurement and Evaluation

CONTRACT FUNDING:

FY	$	SOURCE:
80	67,000	SERI

SUMMARY:

The objective of this effort is to optimize mechanical and electrical design of a four point probe system in such a way that advanced thin film semiconductor films can be characterized for sheet resistivity. This effort when complete will represent an improvement in the four point probe instrumentation state-of-the-art.

The major problem associated with current 4-point probe systems is the probe loading force. ASTM Standard F-374 allows for a probe force of 30 to 80 gf and an induced potential probe voltage of 10 to 20 MV to characterize single crystal films of 0.2 μm minimum thickness. The loading force is considered excessive for advanced photovoltaic thin films. Reduction of the loading force introduces new problems such as:

- higher contact resistance
- increased current source requirement
- local probe heating and induced space charge effects

Another problem associated with film resistivity measurements is possible leakage current to the supporting substrate. The leakage current introduces errors in the absolute resistance value and with present probe systems this leakage current cannot be detected or measured.

Instrument research to date has shown that sheet resistivities in the 10^{12}ohm/□ range are possible.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: The Polka Dot Solar Cell
CONTRACT NUMBER: XS-0-9010-2

CONTRACTOR (NAME AND ADDRESS):
General Electric Company
Corporate Research and Development
P. O. Box 8
Schenectady, NY 12301
TELEPHONE: (518) 385-8103
PRINCIPAL INVESTIGATOR: R. N. Hall

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 4/1/80 **TO:** 3/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/High Efficiency Concentrators

CONTRACT FUNDING:

FY	$	SOURCE
80	99,369	SERI

SUMMARY:

A new silicon solar cell now under development is expected to achieve high efficiency with low-cost manufacture. The cell features an array of interconnection paths to carry photocurrent through the cell to metal electrodes on the rear, thus eliminating the collection grid with its attendant losses. This cell is expected to achieve efficiencies approaching the theoretical limit of 22% for silicon with good lifetime under one sun terrestrial illumination; and higher values in concentrated sunlight. The objectives of this program include: 1) constructing a workable fabrication sequence; 2) appropriate tests to determine cell performance and feasibility; 3) comparison of measured performance with analysis to evaluate basic solar cell junction parameters; and 4) measurement of heavy doping effects to determine the limitations they impose on solar cell performance.

Realization of these objectives will be approached through the following tasks:

A. Application of an analytical model for cell performance, developed previously, to different cell geometries with final selection of a preferred design and implementation of processing techniques and facilities.

B. Variation of fabrication parameters, especially doping levels and impurity profiles, to improve open-circuit voltage, short-circuit current and fill factor. Use of gettering agents will be studied as a means to increase minority carrier diffusion length. Alternatives to conventional junction fabrication techniques will be investigated.

C. Evaluation of the usual solar cell electrical parameters and heavy doping effect parameters through the usual current-voltage tests, spectral response measurements and use of EBIC techniques.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Regenerative Mode Photoelectrochemical Cells in Aprotic Molten Salt Electrolytes	
CONTRACT NUMBER XS-9-8041-17-MOD I	
CONTRACTOR (NAME AND ADDRESS): Gould Incorporated 40 Gould Center Rolling Meadows, Illinois 60008 TELEPHONE: (312) 640-4420 PRINCIPAL INVESTIGATOR: Dr. Jeffrey Phillips	DIRECTING ORGANIZATION AND ADDRESS: Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401 TELEPHONE: (303) 231-1369 PROJECT ENGINEER: Dr. Satyen Deb
CURRENT CONTRACT PERIOD: FROM: 9/15/80 TO: 6/14/81	CONTRACT FUNDING: SOURCE: FY 79 $ 99,980 SERI FY 80 $ 85,000 SERI FY ____ $ ____ ____ FY ____ $ ____ ____ FY ____ $ ____ ____
PROBABLE PROJECT COMPLETION DATE: 6/14/81	
AREA/TASK: Compound Semiconductor /Photoelectrochemistry	

SUMMARY:

The objective of this program is to investigate the advantages that are expected to arise from the use of aprotic room temperature molten salts (RTMS) as electrolytes for photoelectrochemical cells operating in the regenerative mode.

The approach consists of the following tasks:

a. Molten salts such as mixtures of aluminum chloride and alkylpyridinium chloride or bromide, will be prepared and purified. The semiconductors for photoanode will be procured and prepared.

b. Investigate the electrochemical behavior of the semiconductor materials in molten salt electrolytes by cyclic voltammetry. Characterize the photoelectrochemical behavior of the semiconductor - RTMS electrolyte system.

c. Investigate the electrochemical behavior of several redox couples in RTMS electrolytes by cyclic voltammetry.

d. Evaluate the photoelectrochemical stability of the semiconductor/redox couple/ RTMS electrolyte system.

e. Fabricate and characterize the most promising semiconductor photoelectrode/RTMS electrolyte system.

The aluminum chloride-- t- butylpyridinium chloride molten salt electrolyte system has been prepared and characterized. Several redox couples have been characterized by electrochemical means in this system including several ferrocone/ferricinium substituted couples. n-GaAs and n-Si semiconductor photoelectrodes have been characterized in this molten salt using a series of redox couples. Of the cadmium chalcogenide semiconductors, only CdSe was found to be stable enough chemically in this molten salt system to proceed with further experiments. Initial experiments indicate that Si is more stable in molten salt electrolytes than in aqueous solutions.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: Electrochemical Photovoltaic Cell II-VI Compound Thin Film Electrodes
CONTRACT NUMBER: XP-9-8002-8-MOD I

CONTRACTOR (NAME AND ADDRESS):
Grumman Aerospace Corp.
South Oyster Bay Road
Bethpage, NY 11714
TELEPHONE: (516) 575-3286
PRINCIPAL INVESTIGATOR: Dr. Michael A. Russak

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 6/5/80 TO: 6/4/81

PROBABLE PROJECT COMPLETION DATE: 6/4/81

AREA/TASK: Compound Semiconductor/ Photoelectrochemistry

CONTRACT FUNDING:		SOURCE:
FY 79	$ 211,155	SERI
FY 80	$ 221,696	SERI
FY	$	
FY	$	
FY	$	

SUMMARY

The objective of this program is to develop a stable thin film electrochemical photovoltaic cell with a conversion efficiency (AMI) of 10% or greater.

The approach which will be used in this program includes:

1. CdSe Thin Film Electrodes fabricated by co-evaporation of Cd&Se
   - Ti Substrate
   - SnO_2 coated glass
   - $CdSe_xTe_{1-x}$ Thin Film Electrodes by co-evaporation from Cd, Se and Te.
2. Post deposition treatment
3. I-V evaluation
4. Selected further evaluation
   - Optical & electronic
   - Chemical & microstructural
   - PEC
   - Electrolyte variation
5. Correlations among 1 to 4
   Feedback into 1

The current status of the program includes the completion of the basic co-evaporation parametric evaluation and initiation of process variation. Solar energy conversion efficiencies of up to 5.5% have been obtained for CdSe (~5 microns) and up to 5.1% for $CdSe_xTe_{1-x}$ by co-evaporation using CdSe and CdTe.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Measurement Technology for Advanced Solar Cells

CONTRACT NUMBER: DS-9-8146-1

CONTRACTOR (NAME AND ADDRESS):

Hanford Engineering and Development
Laboratory
Richland, WA 99352

TELEPHONE: (509)942-4138

PRINCIPAL INVESTIGATOR: Mr. S. Price

DIRECTING ORGANIZATION AND ADDRESS:

SERI
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 321-1361

PROJECT ENGINEER: Philip R. Pierce

CURRENT CONTRACT PERIOD

FROM: 5/79 TO: 2/81

PROBABLE PROJECT COMPLETION DATE: 1982

AREA/TASK:

Technical Support/Measurement and Evaluation

CONTRACT FUNDING:

FY	$	SOURCE:
79	200,000	SERI
80	250,000	SERI

SUMMARY:

The objectives of this subcontract is to provide physical characterization and chemical analysis of solar cells provided to HEDL by SERI. Review, evaluate and report on current solar cell measurement methods as well as ellipsometry and infrared electro-thermal methods.

Technical reports have been issued as follows:

A. SERI/TR-98146-1, March 1980, Materials Analysis Methods for Examination of Solar Cells.

B. HEDL TC-1548, May 1980, Current Solar Cell Measurement Methods; Review and Evaluation.

C. HEDL TC-1728, July 1980, Applications of Ellipsometry to Solar Cell Research.

D. HEDL TC-1599, July 1980, Electro-Thermal Infrared Scanning Method for Polycrystalline Solar Cells.

Contract continuation is maintained to provide materials characterization support to SERI. Also, a review of minority carrier lifetime measurements in Advanced Research type devices: and electro-thermal instrumentation development will be performed.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Optimization of Transparent Electrode For Solar Cells

CONTRACT NUMBER: RS-0-9318

CONTRACTOR (NAME AND ADDRESS):
President and Fellows of Harvard College
Office of Research Contracts
1750 Massachusetts Avenue
Cambridge, MA 02138

TELEPHONE: (617) 495-4017

PRINCIPAL INVESTIGATOR: Dr. Roy G. Gordon

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1483

TELEPHONE: (303) 231-1483

PROJECT ENGINEER: E. Sabisky

CURRENT CONTRACT PERIOD:
FROM: Oct. 1980 **TO:** Sept. 1981

PROBABLE PROJECT COMPLETION DATE: 1983

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
81	47,000	SERI

SUMMARY:

Solar cells convert sunlight into either electricity or chemicals (including fuels, such as hydrogen). In order to carry out these conversions efficiently, solar cells usually need a surface layer which simultaneously transmits almost all of the incident sunlight, and also conducts electricity very well. Such layers, called transparent electrodes, must also be strong, stable to weathering and sunlight, inexpensive, non-toxic, non-polluting, and composed of sufficiently abundant materials. This long list of requirements is best met by a film of tin oxide made by a new process. The proposed research has as its goal further improvements in the properties of this transparent electrode material. The first phase of the work will seek to find out what it is that now limits the transparency and electrical conductivity of this material. It is suspected that certain chemical impurities, and also mechanical imperfections at boundaries between small grains in the films, may have deleterious effects. The second phase of the work will attempt to remove those deleterious factors which are identified in the first phase. Then all the other experimental factors will be varied systematically to obtain the most transparent and electrically conductive films possible. Finally, some samples of optimal films will be made, under the best conditions obtained.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Investigation of a-Si, a-GaAs and Other Amorphous Semiconductors as Materials for Solar Energy Conversion
CONTRACT NUMBER: XW-0-9358

CONTRACTOR (NAME AND ADDRESS):
Harvard University
Division of Applied Sciences, Pierce Hall
Cambridge, MASS 02138
TELEPHONE: (617) 830-2853
PRINCIPAL INVESTIGATOR: W. Paul (Prof.)

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1497
PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:
FROM: Oct 1980 TO: Oct 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	239,000	SERI
81	230,000	SERI

SUMMARY:

This proposal addresses fundamental questions regarding dangling bond passivation in amorphous materials, a condition necessary for the production of photovoltaic quality material, and the ability to measure the effects of such passivation by observing a reduced gap state density near the Fermi level of the material. In particular, experiments performed under a Harvard-sponsored DOE Contract last year have led to the hypothesis that hydrogen attaches itself, in a compound amorphous semiconductor such as GeSi, preferentially to the element with the greatest bond strength, and thus passivates the dangling bonds of only one of the elements. This may have serious consequences for amorphous silicon material photovoltaic response when attempts are made to vary the material bandgap by introducing other elements such as carbon or germanium into the amorphous matrix. There is also considerable controversy as to the accuracy of present measurement techniques designed to measure gap state densities. Field effect measurements can be dominated by surface or interface states, and other competing techniques are not yet advanced enough to allow a definitive determination of which method gives the most reliable results. The Harvard contract addresses both these questions by providing research support on compound semiconductor materials such as a-GaAs and a-Ge-Si, and also on the different techniques employed in making gap state density measurements on amorphous materials.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Supported Growth of Polycrystalline Silicon Sheet on Low-Cost Ceramic, Carbon, or Reusable Substrate

CONTRACT NUMBER: XS-9-8119-1

CONTRACTOR (NAME AND ADDRESS):

Honeywell Corporate Material Sciences Center
10701 Lyndale Avenue South
Bloomington, MN 55420

TELEPHONE: (612) 887-4359

PRINCIPAL INVESTIGATOR: J. D. Heaps

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1379

PROJECT ENGINEER: Arie P. Ariotedjo

CURRENT CONTRACT PERIOD:

FROM: 9/26/79 TO: 9/30/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 181,696	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The main objective of this project is to identify and develop high-throughput supported-growth methods for producing low-cost, large-area polycrystalline silicon sheet on ceramic or carbon substrates.

To achieve this objective, two silicon coating methods have been investigated. With the first method (SCIM-coating) silicon coatings were produced in a continuous manner by passing a substrate over a molten-silicon meniscus which was contained in a narrow fused-silica trough. With the second method(top-coating), molten-silicon was metered onto the top surface of a moving substrate. In order to pursue the high-throughput objective of the project, fast growth modes were also thermally analyzed and experimentally investigated. Fast growth can be achieved by creating a thermal environment in the solidification zone of the coater whereby the liquid-solid interface forms, at least in part, a small angle ($<5^0$) with the surface of the substrate.

Significant progress has been made in resolving the numerous thermal and growth stability problems associated with SCIM-coating. The evaluation has shown this method to be a viable low-cost technique for producing supported silicon sheet. Thin (80-100 μm) silicon layers have been coated on ceramic substrates. The layers have columnar grains several centimeters in length and as large as 5 mm in width. Electrical characterizations of the layers show minority-carrier diffusion lengths of ~ 25 μm and photodiode V_{oc}'s and J_{sc}'s of 0.5 volt and 23 mA/cm^2 respectively. Fast-growth has not yet been accomplished in SCIM-coating. The two proposed methods for fast-growth, as predicted by the thermal analysis, were, however, verified by dip-coating experiments. In one method, additional heat was applied on the meniscus side in the solidification zone (cold substrate mode); a 300 μm thick layer was grown at a coating rate of 12 cm/min. In another experiment, this additional heat was applied to the substrate (hot substrate mode); a 1.3 mm layer was grown at a coating rate of 12 cm/min.

Evaluation of the top-coating methods proposed has been completed. Within the limit of this study, there does not appear to be a satisfactory way to meter the proper flow of molten silicon onto the substrate. From this study, a unique top-coating method did emerge which should be further investigated.

The evaluation of carbon substrates, to date, indicates that certain grades of carbon have substrate potential and would be cost competitive with mullite.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Investigation of Mechanically Hard, Chemically Inert Antireflection Coatings for Photovoltaic Solar Modules

CONTRACT NUMBER: XS-0-9010-3

CONTRACTOR (NAME AND ADDRESS):

Honeywell, Inc. (Corporate Technology Center)
10701 Lyndale Avenue South
Bloomington, MN 55420

TELEPHONE: (612) 887-4309

PRINCIPAL INVESTIGATOR: Thomas J. Moravec

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1379

PROJECT ENGINEER: Arie P. Ariotedjo

CURRENT CONTRACT PERIOD:

FROM: 4/1/80 **TO:** 3/31/81

PROBABLE PROJECT COMPLETION DATE: 3/31/81

AREA/TASK: Advanced Silicon/ Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
80	99,891	SERI

SUMMARY:

Carbon thin films that possess "diamond-like" properties have been deposited on silicon by radio frequency plasma and ion beam techniques. However, these films exhibit significant visible light absorption. The objective of this program is to understand the nature of the visible absorption, determine the refractive index of the films and attempt to vary deposition conditions in order to minimize the absorption in the diamond-like carbon thin films.

The approach is to use SIMS and ESCA analysis to study contaminants and entrapped gases in the films. Measurements of the UV, visible and IR spectra of the films and calculation of the refractive index and absorption from the spectra have been carried out. Hydrocarbon gas composition and deposition plasma conditions will be varied to study the effect of these parameters upon optical properties of the films.

To date, depositions of "diamond-like carbon films on silicon have been made with two gases in the plasma: ethane and butane. A computer program has been written to determine the optical constants n and k from the measured reflectivity, transmission, and thickness of a film on a transparent substrate. Refractive index (n) values measured for the carbon films on glass slides have averaged out to 2.24 for wavelengths $4000A^{o}$ to $8000A^{o}$. At $6000A^{o}$ wavelength high absorption films have $k=.2$. It has been possible to prepare lower absorption films with $k=.06$ by raising the deposition pressure from 10^{-3} torr to 10^{-1} torr. Solar cells coated with such low absorption films exhibit a 30% increase in efficiency (vs 13% for high absorption films) over an uncoated cell.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Research and Development on InP Solar Cells by Plasma Reactive Deposition
CONTRACT NUMBER: XZ-0-9196-1

CONTRACTOR (NAME AND ADDRESS):
Hughes Aircraft Company
3011 Malibu Canyon Road
Malibu, CA 90265

TELEPHONE: (213) 456-6411
PRINCIPAL INVESTIGATOR: Ken Zanio

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 6/20/80 **TO:** 6/19/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE
79	119,543	SERI
80	64,998	SERI
80	233,453	SERI

SUMMARY:

The objective of this program is to develop the InP/CdS heterojunction system as an all thin film solar cell.

The objectives of the current effort include: 1) deposition of InP on recrystallized CdS by planar reactive deposition at temperatures low enough to suppress interdiffusion; 2) suppression of the sulfur vapor transport to eliminate its contribution to the InP n-type doping; 3) optical and electrical characterization of the InP layers to determine their device quality; 4) evaluation of the InP/RxCdS/ITO/glass structures and correlate the solar cell performance with the InP growth conditions; 5) development of an ITO/p-InP/p+-InP/n+-InP/n recrystallized CdS frontwall device if the thickness of the n-InP layer cannot be reduced in a manner which is consistent with device quality InP growth; and 6) optimization of the all thin film InP/CdS device structure and an assessment of its potential for achieving a conversion efficiency of 10% or greater.

Some of the program accomplishments are:

1. Defined an optimum substrate temperature range of 300°C - 350°C for the deposition of epitaxial p-type InP on RXCdS.
2. Deposited thin films (~ 1 μm thick) and large grains (~ 40 μm x 40 μm) of InP on RXCdS at 280°C by PRD; presently lower substrate temperature restricted by n-type native defects at 300°C.
3. Prepared all thin film InP/RXCdS devices at 380°C with V_{oc} 0.55V but with no light response presumably due to an intermediate n-type layer via S-diffusion from RXCdS.
4. Prepared p-type InP on RXCdS by eliminating S-doping via vapor phase from RXCdS through capping.
5. Increased largest RXCdS grain size to 300μm.
6. Deposited large grains of CdTe (~ 30μm) on RXCdS by physical vapor deposition at 460°C.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Chemistry and Physics of Silicon-Based Amorphous Semiconductors

CONTRACT NUMBER: ZZ-0-9319

CONTRACTOR (NAME AND ADDRESS):
IBM
Thomas J. Watson Research Center
Yorktown Heights, NY 10598
FTS 8-656-9220

TELEPHONE: (914) 945-1338

PRINCIPAL INVESTIGATOR: M. Brodsky

DIRECTING ORGANIZATION AND ADDRESS:
SERI
PVAS
1617 Cole Boulevard

TELEPHONE: Golden, Co 80401 (303) 231-1497

PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:

FROM: Oct 1980 **TO:** Oct 1981

PROBABLE PROJECT COMPLETION DATE: Oct 1983

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
81	175,000	SERI

SUMMARY:

This proposal addresses fundamental questions concerning plasma deposition of hydrogenated amorphous silicon (a-Si:H) films. In particular, the question has been raised as to whether a-Si:H material prepared by glow discharge of silane is the optimum material that can be produced for PV applications, and if not, what can be modified in the deposition process and deposition chemistry to obtain even better material. The IBM proposal addresses the deposition chemistry aspect of this question. They have already deposited films from disilane having seen a sharp increase in both film deposition rates and film photoconductivity, and plan to synthesize other novel precursors for use as feed or dopant gases in the plasma. Particular emphasis will be placed on the incorporation of phosphorus and other dopants into the films using dopant incorporation into silicon containing molecules. In addition, plasma diagnostic techniques such as mass spectroscopy and optical emission spectroscopy will be used to identify intermediate species and reaction pathways leading to film deposition, and to examine the effects of additives on the plasma chemistry. The effect of a bias field shall also be examined to provide information on whether charged species are of direct importance or play a secondary role in film deposition.Such films shall be characterized using appropriate diagnostic techniques, and devices shall be constructed for photovoltaic response when deemed necessary.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Zn_3P_2 as an Improved Semiconductor for Photovoltaic Solar Cells **CONTRACT NUMBER:** XS-9-8062-1	
CONTRACTOR (NAME AND ADDRESS): Institute of Energy Conversion University of Delaware 1 Pike Creek Center Wilmington, DE 19808 **TELEPHONE:** (302) 738-8481 **PRINCIPAL INVESTIGATOR:** Anthony W. Catalano	**DIRECTING ORGANIZATION AND ADDRESS:** Solar Energy Research Institute 1617 Cole Boulevard Golden, CO 80401 **TELEPHONE:** (303) 231-1383 **PROJECT ENGINEER:** Kim Mitchell
CURRENT CONTRACT PERIOD: **FROM:** 9/1/78 **TO:** 2/28/81	**CONTRACT FUNDING:** **SOURCE:** **FY** 79 **$** 425,164 SERI **FY** 80 **$** 305,000 SERI **FY** ____ **$** ____ ____ **FY** ____ **$** ____ ____ **FY** ____ **$** ____ ____
PROBABLE PROJECT COMPLETION DATE:	
AREA/TASK: Compound Semiconductor/Emerging Materials	

SUMMARY:

The objective of this project is to develop high efficiency single crystal and thin film solar cells based on Zn_3P_2.

The objectives of the FY80 supported effort include: 1) continuation of the development and characterization of n-type Zn_3P_2 bulk material to provide support to the p/n junction device development; 2) development and modelling of Zn_3P_2 p/n junction devices to evaluate the mechanisms which control the junction rectification and limit the conversion efficiency; 3) optimization of thin film Zn_3P_2 deposition by close space vapor transport to obtain thin film areas > 1 cm^2; 4) lowering the resistivity of the thin film p-Zn_3P_2 layers to less than 10 ohm-cm by doping with Ag or other appropriate dopants; 5) development and modelling of transparent Mg/Zn_3P_2 Schottky devices which is compatible with the p/n junction device development; and 6) continue as appropriate the investigation of wide bandgap heterojunction devices.

Device quality Zn_3P_2 thin films have been deposited onto mica and ion substrates by close-space vapor transport. All thin film Mg/Zn_3P_2 devices have exhibited total area efficiencies of approximately 3.0% and show potential to increase the conversion efficiency to 5.0% in the near term.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Theoretical Models for Efficiency for Polycrystalline Thin Film Solar Cells

CONTRACT NUMBER: DE-AC01-79ET 23107

CONTRACTOR (NAME AND ADDRESS):
Institute of Energy Conversion
University of Delaware
Newark, DE 19711

TELEPHONE: (302) 995-7155

PRINCIPAL INVESTIGATOR: J. Meakin/A. Rothwarf

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, DO 80401

TELEPHONE: (303) 231-1383

PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:

FROM: 8/31/79 **TO:** 1/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	58,332	DOE

SUMMARY:

The objectives of the program are to develop a fundamental understanding and assess the potential of Schottky and MIS cells based on Zn_3P_2. Theoretical models will be developed for short circuit current open circuit voltage and fill factor. Criteria for the selection of heterojunction partners to Zn_3P_2 will be established.

The loss minimization analysis already successfully applied to CdS/Cu_2S cells will be extended to potential cell designs based on Zn_3P_2.

The status of the program is:

1. A model for MIS solar cells has been developed based upon the presence of pinholes in the I-layer. The model may predict cell behavior more accurately and indicate how more reliable devices can be fabricated.
2. Computer programs for homojunction and heterojunction calculations have been written and single crystal portions are operational.
3. Results of experimental Zn_3P_2 program are being closely followed for subsequent use in calculations and comparison to model results.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Improved Efficiency a-Si Solar Cells

CONTRACT NUMBER: XG-0-9195-1

CONTRACTOR (NAME AND ADDRESS):
Institute of Energy Conversion
University of Delaware
One Pike Creek Center
Wilmington, DE 19808

TELEPHONE: (302) 995-7155

PRINCIPAL INVESTIGATOR: Dr. Vikram Dalal

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1483

TELEPHONE: (303) 231-1483

PROJECT ENGINEER: E. Sabisky

CURRENT CONTRACT PERIOD:
FROM: Feb. 1, 1980 **TO:** Jan. 31, 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/
Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	257,000	DOE
81	356,000	SERI

SUMMARY:

Objective: To develop improved efficiency a-Si solar cell designs and to fabricate improved materials and cells.

Accomplishments:

1. Material Growth:
   - Both hydrogenated and fluorinated a-Si films grown.
   - Doping efficiency high. $\sigma = .05\ (\Omega\text{-cm})^{-1}$ for n^+ a-Si;H and $\sigma = 10\ (\Omega\text{-cm})^{-1}$ for n^+ a-Si:F,H.
2. Material Properties:
   - Reduction of O contamination reduces Egap of a-Si:F:H films to ~1.75 eV.
   - Electron drift mobility measured ~0.2 $\text{cm}^2/\text{V-sec}$.
   - Thermoelectric power used to determine bulk defect density at $\sim 10^{16}/\text{cm}^3\text{-eV}$ near mid-gap.
3. Device Preparation:
   - p^+in^+ cells made on Mo/glass substrates.
   - Diode quality factors reduced to ~1.4, indicating reduction in space-charge recombination.
   - Best $V_{oc} = 0.85$ V, $J_{sc} = 10$ mA/cm^2, FF = 0.56.
   - Shunt resistance is quite high ($>1000\ \Omega\text{-cm}^2$) and diodes are pinhole free. Diodes can withstand reverse fields of 2-3 X 10^5 V/cm.
4. Device Design and Analysis:
   - A comprehensive modeling program has been developed to explain the behavior of a-Si cells in terms of density of mid-gap defect states. Analysis shows achievable J_{sc} of 16mA/cm^2, V_{oc} of 0.9V and FF of 0.72.

- Analysis of cells indicates that series resistance is the major factor in fill factor loss.

TASK B

Joint Program with University of Mexico

- A joint program to pursue a-Si R&D with the University of Mexico has started.
- One Mexican scientist is a resident at Delaware learning about a-Si deposition.

SERI

Photovoltaics AR&D Lead Center

TITLE: Cadmium Sulfide/Copper Sulfide Heterojunction Cell Research

CONTRACT NUMBER: XS-9-8309-1

CONTRACTOR (NAME AND ADDRESS):
Institute of Energy Conversion
University of Delaware
Newark, DE 19711

TELEPHONE: (303) 995-7155

PRINCIPAL INVESTIGATOR: John D. Meakin

DIRECTING ORGANIZATION AND ADDRESS:
SERI/Photovoltaics Program Office
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 9/80 **TO:** 3/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/
Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
79	704,856	SERI
80	300 (approx)	SERI

SUMMARY:

The objective of this project was to produce thin-film polycrystalline solar cells based on the CdS/Cu_2S junction with energy conversion efficiencies of at least 10 percent and expected degradation rates of less than 5 percent in 20 years. The efficiency improvement efforts on this program were directed by loss minimization analysis. Detailed theoretical modeling of the cell was coupled to a broad range of electrical and optical measurements to direct the material and device production leading to progressively more efficient cells.

The program was organized into four tasks: (1) development of improved efficiency of CdS/Cu_2S cells; (2) development of cells based on the (CdZn)S/Cu_2S junction with enhanced open-circuit voltages and higher efficiencies than are possible with CdS/Cu_2S; (3) an experimental and theoretical solar cell analysis effort to provide direction to the other tasks and to achieve a complete understanding of heterojunction photovoltaic devices; and (4) development of an encapsulation system to provide complete hermetic sealing giving the required degree of solar cell durability.

Textured CdSCu_2S cells of 9.15 percent energy conversion efficiency in sunlight have been made. Planar junction cells are expected to exceed 10 percent conversion efficiency and to date up to 8.7% efficiency has been achieved.

Substituting (CdZn)S for CdS increases the open-circuit voltage. Mixed sulfide films have been grown of uniform and controlled composition. The resistivity can be set at the desired value of 1 to $^{10}_{2}$ cm without the addition of extrinsic dopants. Cells with efficiencies in excess of 9.5% have been achieved.

The analysis program has achieved a high level of understanding of the heterojunction and has played a key role in the cell improvement program. The junction field in the CdS can be mapped to give estimates of the interface recombination rate.

The encapsulation and durability task has established the key role played by oxidation of the Cu_2S layer. Development of multilayer antireflection coatings and encapsulants has been started. Various deposition techniques are being explored.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Critical Studies in Materials and Durability

CONTRACT NUMBER: XS-9-8310-1

CONTRACTOR (NAME AND ADDRESS):
Institute of Energy Conversion
University of Delaware
Newark, DE 19711

TELEPHONE: (302) 995-7155
PRINCIPAL INVESTIGATOR: John D. Meakin

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 9/80 **TO:** 3/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
79	193,764	SERI
80	100,000	SERI

SUMMARY:

The objective of this project is to establish the potential for stability in CdS/Cu_2S cells by using different encapsulants and alternate cell designs.

To achieve this objective the following tasks will be carried out: (1) material analysis of potential encapsulants; (2) durability tests of several cell structures; and (3) life projection based on accumulated data.

Accomplishments from previous contract include complete cataloguing of Cu_2S intrusion morphology and analysis of Cu diffusion in polycrystalline substrates. Automated data acquisition system for durability testing have been constructed.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Electrochemical Photovoltaic Cells

CONTRACT NUMBER: XG-0-9175-1

CONTRACTOR (NAME AND ADDRESS): Institute of Gas Technology 3424 S. State Street Chicago, Illinois 60616 **TELEPHONE:** (312) 567-5733 **PRINCIPAL INVESTIGATOR:** A.F. Sammells/P.G. Ang	**DIRECTING ORGANIZATION AND ADDRESS:** Solar Energy Research Institute 1617 Cole Boulevard Golden, CO 80401 **TELEPHONE:** (303) 231-1369 **PROJECT ENGINEER:** Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 4/15/80 **TO:** 4/14/81

PROBABLE PROJECT COMPLETION DATE: 4/14/81

AREA/TASK: Compound Semiconductor/ Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
79	137,916	SERI
80	151,737	SERI

SUMMARY:

The objectives of this program are to experimentally identify semiconductor photoanode/redox couples which show promise of achieving solar energy efficiencies of 10% with polycrystalline material, together with having the potential utility of being used in a bifunctional electrode assembly. The development of such an electrode configuration would allow the reaction products to be conveniently removed for later discharge at porous flow-through and redox electrodes. An all-solid-state photoelectrochemical cell using a solid electrolyte is also being evaluated, which would contain in situ storage.

To achieve the above objectives, the following tasks and subtasks have been identified: 1) identification of high-efficiency electrochemical photovoltaic cells; a) selection of candidate semiconductor/redox couples, b) electrochemical measurements on selected single-crystal semiconductor/redox couples, c) electrochemical measurements on selected polycrystalline semiconductor/redox couples; 2) development of long-life electrochemical photovoltaic cells; a) identification of photoanodic corrosion, and b) stabilization of semiconductor electrodes by the use of nonaqueous electrolytes; and 3) all solid-state electrochemical photovoltaic cell with in situ storage.

Photoelectrochemical characterization of CdSe, $MoSe_2$ and GaAs photoanodes has been performed for application in the redox storage system. The following systems have been evaluated to date: a) CdSe with S^{2-}/S_n^{2} as electron donors together with Te^{2-}/Te_n^{2-} as the electron acceptor at the cathode; b) GaAs with Se^{2-}/Se_n^{2-} as the donor and Te^{2-}/Te_n^{2-} as the acceptor at the cathode; c) $MoSe_2$ with Br^-/Br_2 as the donor and I^-/I_2 as the acceptor at the cathode; d) WSe_2 with Br^-/Br_2 as the donor and I^-/I_2 as the acceptor at the cathode; and e) CdSe with the I_2/I^- couple in an all solid state cell using $AgRb_4I_5$ as the solid electrolyte.

The $MoSe_2$ and WSe_2 single crystal layered compounds have shown the most promise to date in terms of efficiency and stability for redox storage cells. Polycrystalline CdSe materials are currently being evaluated for redox storage cells. The all solid state in situ storage cell has been evaluated in preliminary experiments.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Photoreducing Membranes for Solar Energy Conversion

CONTRACT NUMBER: X5-9-8041-10

CONTRACTOR (NAME AND ADDRESS):
Institute of Gas Technology
3424 South State Street
IIT Center
Chicago, Illinois 60616
TELEPHONE: (312) 567-5846
PRINCIPAL INVESTIGATOR: Dr. G.P. Ang

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 9/25/80 **TO:** 6/24/81

PROBABLE PROJECT COMPLETION DATE: 6/24/81

AREA/TASK: Compound Semiconductor /Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE
79	80,236	SERI
80	61,480	SERI

SUMMARY:

The objective of the program is to demonstrate a new concept for photovoltaic conversion using a system composed of a photoreducing membrane and a redox/oxygen electrochemical cell. The emphasis of the program shall be on identifying a suitable match between the photosensitive membrane and the redox couples/electrolyte system.

In order to fulfill the above stated objective, the following tasks will be performed:

Identification of High-Efficiency, Stable Photoreducing Membranes

The objective of this task is to identify a suitable match among the membrane material, the sensitizer, and the redox couples/electrolyte system. The materials to be evaluated are naturally occurring membrane materials and synthetic membrane materials.

The Integration of Selected Photomembranes

In this task, the complete system composed of the photomembrane cell and the electrochemical cell will be evaluated. Measurements that will be performed in the course of the work will include the following:

- o Determine the current voltage characteristics of the redox/oxygen fuel cell as a function of redox species concentration and the partial pressure of oxygen.
- o Evaluate the effect of electrolyte flow rate (1 to 10 cm/s).
- o Calculate total solar energy conversion efficiency of the system from maximum power output of the redox/air cell relative to the energy of the incident light.
- o Determine the long-term stability of the system by detection of soluble corrosion products using polarographic techniques.

In addition the contractor will investigate and identify potential problems dealing with the design, construction, and operation of the total integrated system, as well as specific components and processes within the system in order to specifically suggest or develop techniques or technology to surmount identified problems.

During this period experiments have been performed to identify the photoelectrochemical characteristics of potentially photoreducing membranes. Membranes selected for evaluation to date have been based on either naturally occurring, synthetic or semiconductor materials. Photopotentials of 53 mV have been observed on phosphatidyl choline membrane synsitized with chlorophyl b. Photocurrents have been obtained with either methylene blue or rhodamine B deposited on the surface of the Nafion membrane. Here the respective oxidation and reduction reactions on each side of this membrane involved water and I^-/I_2. Photopotentials of 20 mV were observed on a dialysis membrane evaporated with CdSe.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: High Efficiency Thin-Film GaAs Solar Cells

CONTRACT NUMBER: XJ-9-8171-1

CONTRACTOR (NAME AND ADDRESS):
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91103

TELEPHONE: (213) 354-6471

PRINCIPAL INVESTIGATOR: Y. C. M. Yeh

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1396

PROJECT ENGINEER: J. Benner

CURRENT CONTRACT PERIOD:

FROM: 7/1/79 **TO:** 10/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK. Compound Semiconductor/Thin Film Gallium Arsenide

CONTRACT FUNDING:

FY	$	SOURCE:
79	258,400	SERI
80	70,000	SERI

SUMMARY:

The objective of this project is to develop the necessary materials technology for fabrication of thin single crystal GaAs solar cells on graded Ge/Si alloy layers on silicon substrates.

The approach includes development of metalorganic CVD capability and demonstration of high efficiency cells grown on GaAs and germanium substrates; addition of a trimethylaluminum source to the reactor to allow flexibility in selection of solar cell structure; and preliminary investigation of techniques for preparation of graded Ge/Si layers on silicon substrates terminating with a single crystal Ge surface.

At present, 18% efficient n$^+$/p shallow homojunction GaAs solar cells have been prepared by MO-CVD using single crystal Ge substrates. The capability for growth of GaAlAs has been added to the MO-CVD facility. Finally epitaxial growth of Ge on Si has been demonstrated using growth temperatures as low as 540°C.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Vacuum Deposited Polycrystalline Silicon Films for Solar Cell Applications

CONTRACT NUMBER: XS-9-8278-1

CONTRACTOR (NAME AND ADDRESS):
The John Hopkins University
Applied Physics Laboratory
Laurel, Maryland 20810

TELEPHONE: (301) 953-7100 ext. 7100

PRINCIPAL INVESTIGATOR: Charles Feldman

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-7299

PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:
FROM: Sept. 29, 1979 **TO:** Dec. 31, 1980

PROBABLE PROJECT COMPLETION DATE: December 31, 1980

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE
78	173,900	DOE
79	100,000	SERI
80	103,000	SERI

SUMMARY:

The project addresses the DOE goal of fabricating low-cost, 10% efficient solar cells through the use of vacuum deposited, thin-film, polycrystalline silicon layers deposited on a substrate/back electrode combination.

The approach involves studying 1) transition metal borides as back electrodes, 2) silicon crystallite growth in films, 3) junction formation procedures, and 4) analyzing compositions and interface interactions by secondary ion-mass spectrometry, scanning electron microscopy and X-ray diffractometry. The investigations lead to an understanding and optimizing of the separate fabrication steps in an envisioned all-vacuum production process.

Solar cells utilizing vacuum deposited polycrystalline silicon layers have been fabricated on TiB_2/alumina ceramic substrates. Junctions (n on p) were formed both by diffusion and by vacuum deposition. The mechanism for large grain growth on TiB_2 layers has been elucidated and an average surface grain size of 30-40 μm has been achieved. Photovoltaic efficiencies (AM1) of up to about 2.6% have been obtained on small, diffused junction solar cells, without anti-reflection coatings. At present, indications are that further improvement in efficiency depends on reducing impurity levels in the silicon films rather than on increasing grain size.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Commercialization of Thick-Film Solar Cells

CONTRACT NUMBER: XS-9-8104-2

CONTRACTOR (NAME AND ADDRESS):

Johnson Controls
5757 N. Green Bay Avenue
Milwaukee, WI 53201

TELEPHONE: (414) 228-2371

PRINCIPAL INVESTIGATOR: Guy D. McDonald

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 9/80 **TO:** 3/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
79	153,975	SERI
80	77,000	SERI

SUMMARY:

The object of this project is to determine the technical and commercial feasibility of fabricating large area, polycrystalline, heterojunction photovoltaic cells using thick film screening and sintering technology and production scale manufacturing equipment.

The cells will be constructed initially from cadmium sulfide/copper sulfide and later from possible other semiconductor combinations. The minimum cell area will be 25 cm^2. The cell components and the total cells will be characterized as to chemical composition, microstructure, electrical properties, and solar cell performance.

Cadmium sulfide films with a range of resistivities have been made by an established screen printing and sintering process using production equipment.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Silicon MIS/Inversion-Layer Solar Cells
CONTRACT NUMBER XS-0-9425-1

CONTRACTOR (NAME AND ADDRESS):
Joint Center for Graduate Study
100 Sprout Road
Richland, WA 99352
TELEPHONE: (509) 375-3176
PRINCIPAL INVESTIGATOR: L.C. Olsen

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1482
PROJECT ENGINEER: R. W. Hardy

CURRENT CONTRACT PERIOD: (Under negotiation)
FROM: 11/80 (est.) TO: 10/81 (est.)

PROBABLE PROJECT COMPLETION DATE. 10/81 (est.)

AREA/TASK. Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

		SOURCE:
FY 80	$ TBD	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this program is to investigate MIS/Inversion-Layer cells theoretically and experimentally. The mechanism of inversion-layer formation is to be determined. Cell efficiency, stability, and reproducibility are to be studied with the ultimate aim of optimization. Limitations to photovoltaic performance are to be determined.

The theoretical approach includes calculation of the effect of fixed oxide charge on sheet resistance. Modelling of grid line density, base resistivity, metal work function, etc. shall be carried out in order to evaluate experimental results.

Inversion-layer cells will be formed by SiO evaporation. Dependence of fixed oxide charge on processing parameters will be determined by C-V measurements. Optimum grid structures will be determined by trying various grid metals and deposition techniques, including photomasking.

Cell characterization techniques to be employed include measurements for light and dark I-V, spectral response, and C-V. All standard cell parameters, including V_{OC}, I_{SC}, FF, and efficiency, will be measured under AM1. Surface concentration profiles obtained by Auger spectroscopy will augment cell stability studies. Stability will be studied under various stresses of illumination, temperature, humidity, and electrical bias. Results will be correlated with models. Encapsulation techniques will be studied.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE Photoacoustic Characterization of Hydrogenated Amorphous Silicon

CONTRACT NUMBER DS-9-8107-1

CONTRACTOR (NAME AND ADDRESS):

Lawrence Berkeley Lab
University of California
Berkeley, CA 94720

TELEPHONE (415) 451-5601

PRINCIPAL INVESTIGATOR: N. Amer

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1497

PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:

FROM April 1980 TO: April 1981

PROBABLE PROJECT COMPLETION DATE: April 1981

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 100,000	SERI
FY 81	$ 110,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

Amorphous silicon-hydrogen (a-Si:H) alloys hold promise for meeting DOE cost and efficiency guidelines for thin film solar cells prior to 1990. In order to achieve the higher conversion efficiencies required, it is necessary that better characterization of the unique optical and transport properties of these materials be achieved. One of the most serious problems to date has been the inability to measure accurately the density of gap states in the a-Si:H material, whose energy profile would enable a better understanding of the intrinsic material, . . . dopant efficiencies and the accompanying Fermi level shifts. Photoacoustic spectroscopy, where the power absorbed from exciting light is detected by the heat produced when such power is dissipated, can be a useful characterization technique in this regard. In addition, by combining this technique with luminescence studies, a full and accurate characterization of the de-excitation of the photo-excited a-Si:H can be achieved.

A set of experiments aimed at investigating the optical properties of hydrogenated amorphous silicon is currently underway. The experiments are designed to yield new information on the details of the optical absorption, the nature of the bandgap, and the electronic properties which determine the photoconductivity.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: Theoretical Determination of Physical Parameters for Solar Cell Materials and Solar Cell Modelling

CONTRACT NUMBER: DS-0-9071-1

CONTRACTOR (NAME AND ADDRESS):

Lawrence Livermore Laboratory
Livermore, CA 94550

TELEPHONE: (415) 422-8700
PRINCIPAL INVESTIGATOR: Jick H. Yee

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 10/1/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

		SOURCE:
FY 79	**$** 150,000	SERI
FY 80	**$** 120,000	SERI
FY	**$**	
FY	**$**	
FY	**$**	

SUMMARY:

The object of this project is to theoretically calculate important optical and transport physical parameters for the new solar cell materials which are important to the characterization of the solar cell, and to model the resultant photovoltaic properties.

The approaches of this project to be taken are:

1. To deduce the optical absorption coefficient through the use of the Kramers-Kronig relation if the reflectivity data existed over a wide range of energies.

2. A pseudopotential energy band technique will be used to study the band structures of the new materials.

3. A normalized concept will be used to study the polycrystalline materials if the average grain size of the material is smaller than the required thickness of the solar cell.

4. Effective masses of the hole, the electron, the mobility, and the minority life-time will be theoretically calculated if these are not available.

Absorption coefficient of Zn_3P_2, Cu_2Se, WSe_2, BAs, $CdSiAs_2$, $CuInSe_2$ and $ZnSiAs_2$ have been theoretically determined. The diffusion length of the minority carriers as a function of the average grain size in these crystals has been calculated. The mobility of the free carriers of these materials has been theoretically investigated. Preliminary modelling of photovoltaic parameters for these materials has also been carried out.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Development of Thin Film WSe_2 Solar Cells **CONTRACT NUMBER:** DS-0-9050-1	
CONTRACTOR (NAME AND ADDRESS): Lawrence Livermore Laboratory Livermore, CA 94550 **TELEPHONE:** (415) 422-8782 **PRINCIPAL INVESTIGATOR:** Dale Miller	**DIRECTING ORGANIZATION AND ADDRESS:** Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401 **TELEPHONE:** (303) 231-1383 **PROJECT ENGINEER:** Kim Mitchell
CURRENT CONTRACT PERIOD: **FROM:** 1/1/80 **TO:** 9/30/80	**CONTRACT FUNDING:** / **SOURCE:** **FY** 80 **$** 120,000 SERI **FY** **$** **FY** **$** **FY** **$** **FY** **$**
PROBABLE PROJECT COMPLETION DATE:	
AREA/TASK. Compound Semiconductor/Emerging Materials	

SUMMARY:

The objective of this program is to evaluate thin film formation of tungsten diselenide (WSe_2) for solar cell applications. Two approaches to form thin film WSe_2 are being evaluated: PlasmaVapor Deposition-Reactive Sputtering and Chemical Vapor Deposition. CVD technique, which involves simultaneous compound synthesis and thin-film growth, offers significant advantages in simplicity and adaptability to commercialization.

Initial evaluation emphasized X-ray diffractometry to help ascertain when stoichiometric WSe_2 was obtained. Hall effect measurements, scanning electron microscopy and optical spectrophotometry were used to estimate mobilities, grain sizes and optical absorption. Direct assessment of lifetimes will later be attempted with coulostatic transient photochemistry techniques recently developed at LLNL. Initial runs with XPS have been made to examine W-Se chemical bonding, to complement the XRD spectra, and to seek major impurities.

Initial analysis indicates that stoichiometric WSe_2 thin films have been achieved by both CVD and reactive sputtering.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Cadmium Sulfide/Copper Sulfide Heterojunction Cell Research
CONTRACT NUMBER: XJ-9-8033-1

CONTRACTOR (NAME AND ADDRESS):
Lockheed Missiles and Space Company
Palo Alto Research Laboratory
3251 Hanover St.
Palo Alto, CA 94304
TELEPHONE: (415) 493-4441
PRINCIPAL INVESTIGATOR: Dr. William Anderson

DIRECTING ORGANIZATION AND ADDRESS:
SERI/Photovoltaic Programs Office
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 2/26/79 **TO:** 6/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/
Cadmium Sulfide

CONTRACT FUNDING:

		SOURCE:
FY 77	$ 250,000	SERI
FY 79	$ 158,971	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

Objective:
The program objective is to investigate and evaluate the application of cylindrical-post-magnetron reactive sputtering to the production of solar-cell quality thin films of CdS/Cd$_2$S for large-scale terrestrial photovoltaic energy conversion.

Approach:
To meet the stated objective, the following five step approach has been adopted:

1) Transport properties of reactively sputter deposited Cu$_x$S films are determined as a function of deposition parameters.

2) Optical and structural characteristics of reactively sputter deposited Cu$_x$S films are determined and correlated with transport properties.

3) Transport properties of reactively sputter deposited CdS and Cd$_{1-x}$Zn$_x$S films are determined as a function of deposition parameters.

4) Optical and structural characteristics of reactively sputter deposited CdS and Cd$_{1-x}$Zn$_x$S films are determined and correlated with transport properties.

5) Photovoltaic properties of reactively sputter deposited heterojunction cell structures are measured and correlated with electrical, optical and structural properties of component layers.

Status:
- o Cu$_2$S deposition parameters have been determined which yield the nearly stoichiometric chalcocite phase.
- o CdS resistivity control has been obtained by (1) sputtering from an In doped Cd cathode and (2) forced deviation from stoichiometry.
- o All sputter deposited cells have been prepared.

This contract will not be renewed beyond the expiration of the current contract period. Lockheed will continue to provide technical support to Telic in form of a subcontractor to Telic.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Amorphous Thin Films for Solar Cell Application (Magnetron Sputtered)

CONTRACT NUMBER: XS-0-9237-1

CONTRACTOR (NAME AND ADDRESS):
Lockheed Missiles & Space Co.
3251 Hanover St.
Palo Alto, CA 94304

TELEPHONE: (415) 493-4411
PRINCIPAL INVESTIGATOR: Dr. Art Jonath

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7039, FTS 327-7039
PROJECT ENGINEER: T. McMahon

CURRENT CONTRACT PERIOD:
FROM: June 1, 1980 TO: May 29, 1981

PROBABLE PROJECT COMPLETION DATE: May 29, 1981

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	230,000	DOE
81	253,000	SERI

SUMMARY:

Magnetron sputtering, a deposition method in which magnetic confinement of a plasma encourages high deposition rates at low working gas partial pressures, is under investigation in this program as a candidate production technology for large-scale manufacture of high-efficiency, thin-film amorphous silicon solar photovoltaic cells. Our approach uses two dc magnetron geometries: (1) a low-cost planar magnetron (PM) system for exploratory and detailed examination of deposition parameter space; and (2) a cylindrical magnetron (CM) system, scalable to production sizes, for deposition of homogeneous films over large areas.

Amorphous silicon films and device structures were sputtered in both PM and CM systems under a wide range of deposition conditions (i.e., T_S, P_{Ar}, P_{H_2}) using both doped and undoped sputter targets. Measured electrical and optical film properties indicate that control over a wide range of conductivity, photoconductivity, conductivity activation energy, and optical and infrared absorption behavior is achievable. Analysis of film oxygen content and distribution profiles indicated that the severe oxygen inclusion by the growing films could be eliminated by a combination of pumping, trapping, and presputter gettering procedures. Films made under these precautionary conditions contain less than 0.1% oxygen.

Multiple depositions to fabricate simple MIS device structures and simultaneously to deposit monitor samples of individual constituent layers have been successful. Such MIS solar cell structures, using semitransparent gold Schottky contacts, have demonstrated photovoltaic behavior. While individual layers, especially the n^+ contact, have yet to be optimized, the projected best results to date are: an $J_{SC}=\frac{3mA}{cm^2}$.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Chalcogenide Glass Solar Cells
CONTRACT NUMBER: DE-AC03-79ET23043

CONTRACTOR (NAME AND ADDRESS):
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139
TELEPHONE: (617) 253-6868
PRINCIPAL INVESTIGATOR: Dr. David Adler

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1370
PROJECT ENGINEER: Jack Stone

CURRENT CONTRACT PERIOD:
FROM: 3/79 TO: 9/30/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: Advanced Silicon/
Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 142,829	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this program is to develop procedures and materials by which high conversion efficiencies can be achieved with inexpensive chalcogenide glass devices.

To meet this objective, the program will focus on means to saturate valance alternation pairs in chalcogenide glasses. This will unpin the Fermi level and eliminate trap-limited mobilities; thereby permitting high conversion efficiencies. Glasses will be doped with several dopants using different procedures to incorporate them. Theoretical considerations suggest that saturation of VAP's will not occur unless non-equilibrium conditions can be maintained in the doped glasses. Thin film samples will be characterized by appropriate electrical, optical, structural (TEM, x-ray), microstructural and chemical procedures.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Advanced Photovoltaic Concentrator Cells

CONTRACT NUMBER: XJ-9-8058-1

CONTRACTOR (NAME AND ADDRESS):

Microwave Associates, Inc.
43 South Avenue
Burlington, Mass. 01803

TELEPHONE: (617) 272-3000

PRINCIPAL INVESTIGATOR: R. Frank/J. Goodrich

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383

PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:

FROM: 8/12/80 TO: 5/12/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/ High Efficiency Concentrator

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 210,259	SERI
FY 80	$ 152,832	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The program objective is to address the various materials and device areas necessary for continued development of advanced concentrator cells with potential conversion efficiencies in excess of 30 percent.

A unique etched multiple vertical junction structure in the back surface of the cell will be fabricated using single crystal silicon with alternating p+ and n+ diffused junctions.

During the first year, Microwave Associates (MA) has been developing new cell processing techniques in order to fabricate both n+ and p+ grooved junctions in the back surface. These techniques involve depositing sequentially a layer of thermal SiO_2, then CVD Si_3N_4, and finally CVD SiO_2. Using photolithography and selective etches, MA has successfully etched and doped the n^+ grooves, then etched and doped the p^+ grooves. In addition, MA has also addressed the reduction of front surface reflection losses and front surface passivation, and the design of the cooling mount to make electrical and thermal coupling to the back-grooved cell. Hydrogen annealing has been identified as one method for reducing the surface recombination velocity of the front surface. A cell mating/interconnect structure has been developed in which metallized Si posts mate to the etched grooves of the cell to make electrical and thermal contact. Further research needs to be carried out to eliminate electrical shunting of the junction introduced by the existing processing procedures, to experimentally verify the theoretical model of cell performance, to improve the short-circuit current, open-circuit voltage, and fill factor of the EMVJ Si cell in order to acheive an efficiency goal of at least 25 percent at the end of the contract period, and to complete development of the electrical and thermal cooling mount.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Amorphous Silicon Thin Film Heterojunction Solar Cells

CONTRACT NUMBER: XJ-0-9056-1

CONTRACTOR (NAME AND ADDRESS):
Mobil Tyco Solar Energy Corp.
16 Hickory Drive
Waltham, MA 02154

TELEPHONE: (617) 890-0909

PRINCIPAL INVESTIGATOR: Ms. Mary Cretella

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401
FTS 327-1483

TELEPHONE: (303) 231-1483

PROJECT ENGINEER: E. Sabisky

CURRENT CONTRACT PERIOD:
FROM: March 1, 1980 **TO:** Feb. 28, 1981

PROBABLE PROJECT COMPLETION DATE: Feb. 1981

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	219,000	DOE
81	233,757	SERI

SUMMARY:

The materials science approach of this program has addressed reducing the non-radiative recombination in the a-Si(H) films; reducing the density of gap states and defects in general; and optimizing the energy gap for solar energy conversion.

To accomplish these objectives we have:

- Attempted to create a more fully coordinated matrix structure by substituting Group IVA elements (C, Ge and Sn) either singly or in combination for part of the silicon.
- Attempted to decrease the remaining defects in hydrogenated material by adding alkali metals (Li, Na, K) to the plasma to interact directly with the defects or to modify and increase the efficiency of the hydrogen defect compensation.
- Determined the variation of optical energy gap and other properties as a function of alloy composition and impurity (doping) levels.

The reference baseline a-Si(H) films show an absorption peak for the Si-H stretching mode at 2000 cm^{-1} and a peak for the rocking mode at 630 cm^{-1}. The films have a density of gap states of 5×10^{15} and a hole diffusion length of 0.3 μm. These films in a non-AR coated, nonoptimized p-i-n solar cell configuration give $V_{OC} = 0.85$ Volts and an efficiency of ~ 2.0% with $E_{og} = 1.8$ eV.

Some of the results we have obtained with our a-Si(H) material modification experiments can be briefly summarized as follows:

- The addition of C to the a-Si(H) network shows the complete shift of the Si-H stretching mode frequency to 2100 cm^{-1} from 2000 cm^{-1} and a variation in E_{og} (with C concentration) to values of 2.4 eV.
- The addition of C + Ge changes the character of the Ge incorporation and the distribution of hydrogen in the alloy network. These films show very little photoconductive behavior.
- The addition of Na gives films which are n-type. Although the a-Si(H, Na) films show little change in photoconductive behavior over the a-Si(H) they do not yield good photovoltaic devices in our standard p-i-n configuration.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Emerging Materials for Solar Cell Application-Electrodeposited CdTe

CONTRACT NUMBER: XS-0-9152-1

CONTRACTOR (NAME AND ADDRESS):

Monosolar Inc.
A Subsidiary of Monogram Ind. Inc.
100 Wilshire Boulevard, Suite 600
Santa Monica, CA 90401

TELEPHONE: (213) 451-8151

PRINCIPAL INVESTIGATOR: Robert L. Rod, PhD

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383

PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:

FROM: 2/15/80 **TO:** 9/15/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductors/Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	221,387	DOE
80	134,076	SERI

SUMMARY:

The objective of this project is to fabricate efficient low cost, large area, thin film CdTe solar cells by electrodeposition techniques developed earlier by Monosolar. There should be at least one cell with a 4% efficiency.

The effort includes three major research tasks as follows:

1. Fabricate n and p-type CdTe thin films. Characterize these films with reference to chemical, physical and electrical parameters.

2. Fabricate 1 inch square ITO/CdTe solar cells in which the CdTe film is electroplated over the ITO and has a pinhole population insufficient to degrade performance. These cells shall be characterized under solar simulation for I-V curves as a function of CdTe plating temperature, layer thickness, stoichiometry, doping, and other closely related factors.

3. Estimate the performance of such cells in terms of measurable material parameters using theoretical models for solar efficiencies.

The CdTe films that have been produced are n-type with grain size of 0.2μ. Diffusion lengths in these films are between 0.05 and 0.1μ. Resistivities are about 2×10^4 Ω-cm.

Schottky cells produced have AM1 efficiencies of about 2% with V_{OC} - 0.53 volts and J_{SC} - 4.5 mA/cm^2.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Sequential Purification & Crystal Growth for the Production of Low Cost Silicon Substrates

CONTRACT NUMBER: XS-9-8119-3M

CONTRACTOR (NAME AND ADDRESS):

Motorola, Inc.
Semiconductor Group
5005 E. McDowell Road
Phoenix, AZ 85008

TELEPHONE: (602) 244-4616

PRINCIPAL INVESTIGATOR: Ming Liaw

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7299

PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD: FROM: 9/79 TO: 6/81

PROBABLE PROJECT COMPLETION DATE: 6/81

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE
79	210,000	SERI
80	172,798	SERI

SUMMARY:

The objective of this program is to develop techniques for the production of low cost substrates for polycrystalline silicon solar cells. Metallurgical grade silicon is used as starting material. The sequential purification and crystal growth technique is used for the production of silicon. The following summarizes achievement to date by each step of the sequential purification.

1. Chemical Leaching: HCl or aqua regia has been used as a leachant. Impurity removal as a function of leaching time has been studied. Reductions of metallic impurities about one order of magnitude have been obtained.

2. Phase separation: Techniques using physical separation or vacuum treatment have been developed to separate insoluble impurities from molten silicon. The major elements in the insoluble impurities are Ca and Al.

3. Reactive gas treatment: No consistent or reproducible results were obtained when molten silicon was treated by Cl_2, HCl, SiF_4 or H_2O.

4. Slagging: Considerable amount of Al and Sr can be extracted by contacting molten silicon with melts of the mixed oxides $CaO-SiO_2$ or $CaO - MgO-SiO_2$.

5. Ingot Pulling: Purification by impurity redistribution using ingot pulling has been found to be the most effective technique. Reduction of impurity concentration by two orders of magnitude or more has been observed.

Silicon wafers produced by this project have ranged from 3" to 5" in diameter. The impurity concentration is equivalent to that in semiconductor grade silicon with the exceptions of boron, phosphorous, oxygen and germanium. Preliminary experiments have been conducted on solar cell fabrication. 7% efficiency was obtained for solar cells fabricated on epitaxial layers.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Thin Film Polycrystalline Silicon Solar Cells

CONTRACT NUMBER: XS-9-8277-1

CONTRACTOR (NAME AND ADDRESS):

Motorola, Inc.
5005 East McDowell Road
Phoenix, AZ 85008

TELEPHONE: (602) 244-6413

PRINCIPAL INVESTIGATOR: Kalluri R. Sarma

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1379

PROJECT ENGINEER: Arie P. Ariotedjo

CURRENT CONTRACT PERIOD:

FROM: 9/25/79 **TO:** 9/25/80

PROBABLE PROJECT COMPLETION DATE: 9/25/80

AREA/TASK: Advanced Silicon/ Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
76	237,450	DOE
77	256,320	DOE
78	290,137	DOE
79	200,000	SERI
80	116,827	SERI

SUMMARY:

The objective of this research program is to develop low-cost processes for producing efficient thin-film polycrystalline silicon solar cells.

To meet this objective, an approach consisting of the following four tasks is being pursued: 1) investigation of a semicontinuous plasma deposition system as a means for efficient, high rate deposition of microcrystalline silicon films; 2) development of low-cost reuseable substrates for deposition and shear separation of silicon films; 3) optimization of subsequent grain enhancement of the films through laser RTR recrystallization; and 4) demonstration of at least 12% efficient, large area (greater than 10 cm^2) solar cells fabricated on grain enhanced silicon films.

The semicontinuous plasma deposition system has been successfully employed for producing microcrystalline silicon films. Efficiency of this system was found to be up to 5% higher in the plasma deposition mode compared to a CVD mode of operation. With periodic resurfacing, molybdenum temporary substrates can be reused, and are expected to meet the low-cost goals. By optimization of RTR laser recrystallization conditions, high chemical purity, low (crystal) defect density, and low residual stress silicon films were produced. However, further work remains to be done to achieve this under higher throughput conditions. Solar cells up to 12% AM1 efficiency were produced on grain enhanced 2 cm x 2 cm silicon films. Initial large area (30 cm^2) solar cells have exhibited AM1 conversion efficiencies of up to 10%.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: PHOTOVOLTAIC MECHANISMS IN POLYCRYSTALLINE THIN FILM SOLAR CELLS
CONTRACT NUMBER: XZ-0-9234

CONTRACTOR (NAME AND ADDRESS):
MOTOROLA INC.
5005 East McDowell Road
Phoenix, Arizona 85008

TELEPHONE: (602) 244-6330
PRINCIPAL INVESTIGATOR: Bhushan L. Sopori

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-7299
PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:
FROM: July 30, 1980 **TO:** August 29, 1981

PROBABLE PROJECT COMPLETION DATE: August 29, 1981

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
1979	204,243	DOE
1980	170,257	SERI

SUMMARY:

Objectives of this program are: 1) development of surface preparation techniques to aid in the unequivocal interpretation of grain boundary (G.B.) data; 2) characterization of G.B.'s in terms of chemical, physical, electrical and optical parameters, and correlation to solar cell performance; 3) identification of the effects of intra grain crystal defects; and 4) determination of effects of solar cell processing on G.B. parameters and bulk defects.

Substrates/cells are analyzed using a variety of electrical/optical measurement techniques to determine local variations in photovoltaic (P.V.) parameters as well as overall cell characteristics. The P.V. parameters are then related to defect/G.B. characteristics by determining the types and densities of intragrain defects and other G.B. parameterssuch as misfit angle, local stresses, and G.B. I-V characteristics. Two types of cells (fabricated on RTR ribbons and Wacker Silso) are used for this study: (1) large area ($>2cm^2$) to correlate local variations with overall cell characteristics; and (2) small area (50 mil diameter) to isolate dependences of type and density of defects/G.B.s on cell parameters.

The following techniques have been developed and are being used for this study: (1) two wavelength laser scanning; (2) optical birefringence to determine local stresses; (3) defect characterization by chemical etching and I.R. microscopy; (4) voltage pick-off probe for G.B. characterization; (5) an optical technique for determination of grain orientations; and (6) standard I-V characterization and spectral response analysis of cells.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE A Program on Solar Cell Measurement Technique Development

CONTRACT NUMBER DS-0-9313-1

CONTRACTOR (NAME AND ADDRESS):
National Bureau of Standards
Electron Devices Division
Washington, DC 20234

TELEPHONE

PRINCIPAL INVESTIGATOR Dr. M. Bullis

DIRECTING ORGANIZATION AND ADDRESS:
SERI
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 321-1361

PROJECT ENGINEER: Philip R. Pierce

CURRENT CONTRACT PERIOD:

FROM: 7/80 TO: 9/80

PROBABLE PROJECT COMPLETION DATE: 12/80

AREA/TASK Technical Support/Measurement and Evaluation

CONTRACT FUNDING:

		SOURCE:
FY 78	$ 226,900	DOE
FY 79	$ 200,540	DOE
FY 80	$ 50,000	SERI
FY	$	
FY	$	

SUMMARY

The main objective of the project is to develop improved solar cell measurement techniques.

The approach involves obtaining spatial point-by-point information about cell design, fabrication and operation using a laser flying-spot scanner and scanning techniques developed at NBS.

The contract performance period has covered approximately three (3) years with initial funding provided by DOE. The present contract is to evaluate the mathematical modules developed by the University of Southern California using the scanner. These models provide analytical predictions for the results of scanning forward-biased perfect cells, and of cells with various defects, i.e., cells with point shorts, and cells cracked with and without shunt conductance across the crack.

These results are applicable to cells made from exploratory materials, e.g., polycrystalline cells, as well as single-crystall cells. Reference Structure Array (RSA) wafers have been fabricated from single-crystal silicon. Each wafer incorporates four, small (1 cm by 1 cm), solar cells. Three of the cells contain precisely designed "defects," and all four are surrounded by solar cell tests pattern NBS-22 for an independent assessment of the cell and "defect" parameters. The RSA cells will be laser scanned under controlled insolation conditions and the scanning results will be compared with those predicted from the University of Southern California work with the objective of putting laser scanning of solar cells on a firm analytic base.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Lifetime of Minority Charge Carriers in Electronic Materials

CONTRACT NUMBER: XS-9-8280-1

CONTRACTOR (NAME AND ADDRESS):
Naval Ocean Systems Center
Electronic Materials Science Div.
San Diego, CA 92152

TELEPHONE: (714) 225-6591

PRINCIPAL INVESTIGATOR: Dr. H. Wieder

DIRECTING ORGANIZATION AND ADDRESS:
SERI
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1361

PROJECT ENGINEER: Philip R. Pierce

CURRENT CONTRACT PERIOD:
FROM: 9/79 TO: 2/81

PROBABLE PROJECT COMPLETION DATE: 2/81

AREA/TASK:
Technical Support/Measurement and Evaluation

CONTRACT FUNDING:

FY	$	SOURCE:
79	90,000	DOE/SERI
80	60,000	SERI

SUMMARY

The objective of this research program is to study the fundamental properties of solar cell electronic materials, specifically with those parameters of polycrystalline materials which affect the recombination of optically induced charge carriers and with an explicit evaluation of their charge carrier lifetime. The approach will be to:

Measure and determine minority carrier lifetimes on polycrystalline semiconducting materials; concentrating initially on the intermetallic semi-conducting III-V alloys, to compare these minority carrier lifetimes with the minority carrier lifetimes of corresponding single crystal materials and to relate these lifetimes to the thickness, grain size, crystallographic orientation and distribution of crystallites in these bulk materials and heteroepitaxial layers grown on a variety of substrates.

Correlate the electrical and galvanomagnetic parameters of the polycrystalline materials investigated with optical and electro-optic coefficients, develop appropriate physical model(s) and equivalent circuit(s) and emphasize, in particular, minority carrier lifetime.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: First Principle Theory of Hydrogenated Silicon
CONTRACT NUMBER: DS-0-9141-1

CONTRACTOR (NAME AND ADDRESS):
Naval Research Laboratory
X-Ray Optics Branch
Washington, DC 20375

TELEPHONE: 202-767-3934
PRINCIPAL INVESTIGATOR: D. Papaconstantopoulos

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1497 FTS 327-1497
PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:
FROM: March 1980 **TO:** March 1981

PROBABLE PROJECT COMPLETION DATE: March 1981

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 93,000	DOE
FY 80	$ 93,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The coherent potential approximation (CPA) method has been used to obtain the electronic states of a random substitutional alloy of Si, vacancies, and hydrogen. The results of the calculations demonstrate the "cleaning" of the gap states upon hydrogenation and characteristics of both the valence and conduction bands in agreement with experimental observations.

We are at present extending the CPA theory in order to include the effects of topological disorder and hydrogen induced off-diagonal randomness.

We have also used the self-consistent pseudopotential method to determine the electronic structure of the hydrogen saturated vacancy (HSV) in Si, in which the four dangling bonds at an ideal Si vacancy are terminated by H atoms. The vacancy dangling bond states are found to be removed from the gap and the H-H interactions do not interfere with the formation of a strong H-Si bond. These results suggest that similar complexes may relieve strain in a-Si upon hydrogenation. This calculation also reveals a potentially observable acceptor state if a HSV-like defect can be created in crystalline Si.

The next step in this approach will be to study relaxation in the HSV and related complexes through the calculation of forces and total energies.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: NMR Studies of Hydrogenated Amorphous Silicon

CONTRACT NUMBER: DS-0-907301

CONTRACTOR (NAME AND ADDRESS):

Naval Research Laboratory
4555 Overlook Ave.
Washington, D.C. 20375

TELEPHONE: (202) 767-3692

PRINCIPAL INVESTIGATOR: Dr. P.C. Taylor

DIRECTING ORGANIZATION AND ADDRESS:

SERI/PVAS
1617 Cole Blvd.
Golden, CO 80401
FTS 327-7039

TELEPHONE: (303) 231-7039

PROJECT ENGINEER: T. McMahon

CURRENT CONTRACT PERIOD:

FROM: 3/15/80 **TO:** 3/14/81

PROBABLE PROJECT COMPLETION DATE: 3/81

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 122,000	DOE
FY 81	$ 130,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The general objective of the present experimental studies has been to achieve a better understanding of the details of the incorporation of the hydrogen in the structure of a-Si:H. Both nuclear magnetic resonance (NMR) and small angle X-ray scattering (SAXS) measurements have been performed on samples of a-Si:H prepared at several different laboratories by the glow discharge technique. These samples have also been characterized by infrared absorption, photoluminescence (PL) and ESR measurements. Samples from facilities at the University of Chicago, RCA Research Laboratories, Brookhaven National Laboratory, and NRL have been investigated during the past year. The general objective of the NRL sample preparation facility has been to produce and characterize the relatively large samples necessary for NMR and SAXS measurements.

The research during the past contract year has demonstrated the utility of the NMR technique as a tool for investigating the local bonding environment of the hydrogen atoms in a-Si:H, but several very significant questions remain concerning the initial results. There is a lack of any detailed microscopic picture for the two distinct ^{1}H NMR sites. In addition, the nature of the hydrogen-associated disorder modes has yet to be elucidated, and corroborative evidence for these modes from complimentary experimental techniques (such as ultrasonic or surface wave attenuation) should be obtained. In the first year we have concentrated on understanding those features of the ^{1}H NMR which are universally observed. In the future we would like to assess the role of impurities in affecting the details of the low temperature spin lattice relaxation rates. The effect of T_1 of increasing the hydrogen content in the films (which generates a more polymeric structure) is also of considerable interest for assessing the nature of the hydrogen-associated disorder modes.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Preparation and Characterization of Sputtered Amorphous Silicon

CONTRACT NUMBER: DS-9-8142

CONTRACTOR (NAME AND ADDRESS):

Naval Weapons Center
China Lake, CA 93555

TELEPHONE: (314) 939-3852

PRINCIPAL INVESTIGATOR: T. Donovan (Dr.)

DIRECTING ORGANIZATION AND ADDRESS:

SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7039

PROJECT ENGINEER: T. McMahon

CURRENT CONTRACT PERIOD:

FROM: June 1, 1980 TO: May 31, 1981

PROBABLE PROJECT COMPLETION DATE: May 31, 1981

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	135,000	SERI
81	145,000	SERI

SUMMARY:

Magnetron deposited films have been shown to have little contamination compared to RF diode deposited layers, ($H = .003$, $0 \leq 0.005$ vs. .01 to 0.3 for the RF diode) deposited layers, the absorption in the $0.5 < E < 1.5$ region is comparable, suggesting this absorption is defect related with both sputtering techniques yielding films with similar defect concentrations. Future work will be directed at attempts to lower the macroscopic defect concentration by varying the substrate temperature and bias, deposition rate, sputter gas composition and pressure and monitoring changes in structure by transmission electron microscopy measurements. The goal will be to discover why the magnetron film is so reactive. The only way to fabricate Schottky diodes was to grow the Pt or Pd contact on top of the a-Si without a break in vacuum. Finally, the present doping studies will be continued with an emphasis on phosphorous, nitrogen, and oxygen.

Date: September 1980

100

SERI

Photovoltaics AR&D Lead Center

TITLE: Studies of Fundamental Growth Problems in Lattice Matched Solar Cells

CONTRACT NUMBER: XS-9-8041-6

CONTRACTOR (NAME AND ADDRESS):
North Carolina State University
Raleigh, North Carolina 27607

TELEPHONE: (919) 737-2330
PRINCIPAL INVESTIGATOR: John R. Hauser

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 9/25/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/High Efficiency Concentrators

CONTRACT FUNDING:

FY	$	SOURCE:
79	97,260	SERI
80	68,685	SERI

SUMMARY:

The study addresses the fundamental growth problems in lattice mismatched III-V semiconductor layers which have applications to multijunction cascade solar cells. The program objective is to investigate techniques for improving the grown quality of lattice mismatched semiconductor layers.

After a period of constructing and debugging the organometallic chemical vapor deposition system, NCSU has grown undoped GaAs layers with a p-type background doping of $5 \times 10^{15}/cm^3$, n-type Te-doped GaAs layers with carrier concentrations up to $2.4 \times 10^{18}/cm^3$, and AlGaAs layers with Al composition ranging from 2% to 70%. In addition, preliminary layers of GaInAs with up to 20% In have been grown. This baseline work provides the basis for pursuing the effects of substrate orientation and nucleation control which are outlined in the program.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Photovoltaic Devices Utilizing III-V Compound Semiconductor Super Lattice
CONTRACT NUMBER: Structures XS-0-9010-4

CONTRACTOR (NAME AND ADDRESS):

North Carolina State University
Raleigh, North Carolina 27607

TELEPHONE: (919) 737-2309
PRINCIPAL INVESTIGATOR: M. A. Littlejohn

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 3/15/80 **TO:** 3/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/High Efficiency Concentrators

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 99,751	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The study addresses the use of superlattices for overcoming the problem of lattice mismatch and bandgap optimization in cascade solar cell structures. In addition this program will shed new light on the basic growth mechanisms and resulting material and solar cell device properties of compound semiconductors grown by organo-metallic chemical vapor deposition (OM-CVD) and molecular beam epitaxy (MBE). The objective of this program is to study the basic problems pertaining to the utilization of compound semiconductor superlattice structures for solar cell applications. The program goal is to determine the potential of superlattice structures for alleviating lattice mismatch and optimizing bandgaps in cascade solar cells in order to ultimately provide low cost, high efficiency solar energy conversion for terrestrial applications.

The approach to achieving the program goal is through performance of the following tasks:

A. Semiconductor superlattice layers of a few micrometers total thickness, consisting of (1) alternating layers of doped and undoped $Ga_{1-x}Al_xAs$ and GaAs, and (2) alternating GaAlAs/GaAs superlattice structure shall be grown by OM-CVD to yield a material with a bandgap of between 1.6eV and 1.8eV, depending on layer thickness and composition value chosen. The Ge/GaAs superlattice structure shall be grown by MBE to yield a material with an adjustable bandgap between 1.0 and 1.2eV.

B. Basic electrical and optical property measurements shall be made on the superlattice layers. These measurements include optical absorption, photoluminescence, resistivity and Hall effect, all versus temperatures as well as Auger analysis to evaluate the nature of the superlattice heterojunction interface. Other physical evaluations (e.g., TEM) shall be carried out if appropriate.

C. Work shall be conducted to study the doping properties of the superlattice structures for the formation of p-n junctions and tunnel junctions. In addition metal semiconductor interfaces to the superlattice layers shall be fabricated for evaluation of Schottky barrier and ohmic contact formation. Devices containing these barriers and/or junctions shall be evaluated for the usual photovoltaic characteristics. A direct comparison with other material systems under study will be made and an assessment of the potential application of superlattice structures to photovoltaic devices will be carried out.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE Infrared Studies of Hydrogentated Amorphous Silicon

CONTRACT NUMBER HZ-0-9238

CONTRACTOR (NAME AND ADDRESS)
North Carolina State University
Raleigh, N.C. 27650

TELEPHONE (919)737-2512

PRINCIPAL INVESTIGATOR Dr. G. Lucovsky

DIRECTING ORGANIZATION AND ADDRESS:
SERI
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1361

PROJECT ENGINEER: Philip R. Pierce

CURRENT CONTRACT PERIOD:

FROM: 5/80 TO: 5/81

PROBABLE PROJECT COMPLETION DATE 5/81

AREA/TASK
Technical Support/Measurement and Evaluation

CONTRACT FUNDING:

FY	$	SOURCE:
80	65,000	SERI

SUMMARY

The purpose of this subcontract is to investigate infrared absorption spectroscopy as a technique for the quantitative analysis of important alloy constituents (hydrogen, oxygen and fluorine) in amorphous silicon thin films. The major scientific issues are (i) the homogeneity of the films and the extent to which an exponential law for absorption can apply, and (ii) the induction effects on both frequencies and oscillator strengths of Si-H vibrations that are produced by a non-statistical distribution of second-neighbor pairs of alloy atoms; e.g., hydrogen and oxygen atoms that are bonded to the same silicon atom.

The research program is to be implemented as follows:

1. Determine the validity of an exponential absorption law for films containing only Si and H, but prepared in different ways, e.g., by glow discharge decomposition of SiH_4 and reactive sputtering.
2. Study the induction effects (on a quantitative basis) associated with second-neighbor pairings, in particular, changes in the oscillator strength of SiH vibrations due to highly electronegative second neighbor atoms, oxygen and fluorine.
3. Compare the results of infrared transmission spectroscopy with other quantitative analysis techniques such as Nuclear Resonance (NR) and ultra-high vacuum Secondary Ion Mass Spectrometry (SIMS).

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Compensation of Dangling-Bond Defects in a-Si, Ge Alloys

CONTRACT NUMBER:

CONTRACTOR (NAME AND ADDRESS):
North Carolina State University
Raleigh, NC 27650

TELEPHONE: (919) 737-2512

PRINCIPAL INVESTIGATOR: Gerald Lucovsky (Prof.)

DIRECTING ORGANIZATION AND ADDRESS:
SERI
PVAS
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7039

PROJECT ENGINEER: T. McMahon

~~CURRENT~~ CONTRACT PERIOD:

FROM: Dec .1980 **TO:** Dec 1981

PROBABLE PROJECT COMPLETION DATE: Dec 1983

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE
81	74,000	SERI

SUMMARY:

Defect neutralization in a-Si, Ge alloys by univalent atoms, hydrogen and the halogens will be studied theoretically and experimentally. Application of a local atomic model based on the chemical properties of the constituent atoms, indicates that hydrogen will preferentially attach to Si atom sites in a-Si, Ge alloys. We propose to test this model by preparing alloy films via sputtering and glow discharge decomposition techniques. Hydrogen and fluorine incorporation will be studied by infrared absorption, and defect environments will be probed by ESR, photoconductivity and optical absorption. Optimization of those optical and electrical parameters of this alloy system which are essential in solar energy conversion applications will be attempted, based on the results of the defect neutralization studies which are proposed.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE Characterization of Solar Cells Using a Modulated Electron Beam
CONTRACT NUMBER XS-9-8313-1

CONTRACTOR (NAME AND ADDRESS):

Northrop Res. and Tech Center
One Research Park
Palos Verdes Peninsula, CA 90274

TELEPHONE: (213)377-4811
PRINCIPAL INVESTIGATOR: Dr. S. Othmer

DIRECTING ORGANIZATION AND ADDRESS:

SERI
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303)231-1361
PROJECT ENGINEER: Philip R. Pierce

CURRENT CONTRACT PERIOD:
FROM: 9/79 TO 9/80

PROBABLE PROJECT COMPLETION DATE: 9/81

AREA/TASK:
Technical Support/Measurement and Evaluation

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 100,000	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY

The objective of this program is to establish a novel technique to characterize thin film solar cells in terms of their transport and recombination lifetime properties by means of a modulated beam of a scanning electron microscope, in conjunction with more conventional measurements using optical excitation.

In the proposed work, an existing electron beam test facility will be augmented and improved to implement the experimental methods, and an optical test facility will be modified to permit complementary testing using an optical probe under realistic solar cell operating conditions. Solar cell test devices form a number of candidate technologies for low-cost terrestrial photovoltaic applications will be examined using these new electron beam techniques, and will be characterized in terms of their transport and recombination properties. Suitable analytical techniques will be refined for interpretation of the data and for predication of optical response. Predictions will be tested by characterization of the photovoltaic response under appropriate conditions of optical and electrical bias.

The technique has been demonstrated at the laboratory level on single crystal solar cells.

A ten month technical progress report shows instrument development work has been essentially completed and some limited solar cell characterization has started.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Applications of Laser Annealing and Laser-Induced Diffusion To Photovoltaic Conversion

CONTRACT NUMBER: DS-0-9078-1

CONTRACTOR (NAME AND ADDRESS):

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

TELEPHONE: (615) 574-5781

PRINCIPAL INVESTIGATOR: R.F. Wood

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-7299

PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:

FROM: 3/80 **TO:** 2/81

PROBABLE PROJECT COMPLETION DATE: 2/81

AREA/TASK: Advanced Silicon/ Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
80	227,800	SERI

SUMMARY:

The objectives of this program are to explore the use of laser annealing and laser-induced diffusion techniques in studies of: low-cost junction formation in polycrystalline silicon; homojunction formation in GaAs without encapsulation; grain boundary effects in both silicon and GaAs; and determination of the extent to which lasers can be used to induce grain growth and to control the diffusion of impurity and substrate atoms from low-cost substrates into deposited layers.

The approach used in this research is primarily an experimental one but some theoretical support has been given and more is anticipated in the future. Experimental techniques used in the laser annealing and photovoltaic work include many types of electrical property measurements, transmission electron microscopy (TEM), ion implantation, channeling and backscattering studies, secondary ion mass spectroscopy (SIMS), x-ray diffraction studies, Raman and infrared, deep level transient spectroscopy (DLTS), scanning electron microscopy (SEM) with electron beam-induced current (EBIC) capability. The properties of finished solar cells are evaluated by standard techniques.

Modifications to existing electron-beam equipment have been made and the modified equipment is in use. It was decided to build both Si and GaAs CVD systems and this has caused some delays, but it will greatly enhance the flexibility of the program. Good progress has been made in establishing the basic parameters for laser annealing of single crystal GaAs ion-implanted with Mg, Zn, and Se. Preliminary studies of the laser recrystallization of sputter-deposited GaAs films have been completed. All elements for the fabrication of ion-implanted laser-annealed GaAs homojunction cells have been tested and the first cells will be fabricated shortly. Studies of the pulsed-laser annealing of polycrystalline Si are carried out. Thin films of Si have been e-beam deposited on various substrates and laser irradiated. Films regrown on both single crystal and polycrystalline Si substrates are of reasonably good quality. Films deposited on Al, Mo, and stainless steel are of poor quality after laser irradiation. Numerous SIMS profiles have been taken of the interpenetration of Si in deposited Si films and the substrate material and the results are being analyzed. Little or no success in passivating grain boundaries by atomic hydrogen has been achieved but some very encouraging results using lithium diffusion have been obtained. Basic studies of grain boundary effects have begun with an emphasis on establishing correlations between the electrical activity of grain boundaries, as measured by EBIC and scanning laser spot techniques, and their microscopic structure, as measured by TEM.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: Photoelectric Properties of Amorphous Silicon Deposited by the Pyrolitic Decomposition of Silane

CONTRACT NUMBER: XS-9-8041-8

CONTRACTOR (NAME AND ADDRESS):

Optical Sciences Center
University of Arizona
Tucson, AZ 85721

TELEPHONE: (602) 626-2263

PRINCIPAL INVESTIGATOR: Prof. B. O. Seraphin

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7039

PROJECT ENGINEER: T. McMahon

CURRENT CONTRACT PERIOD:

FROM: 10/80 TO: 6/81

PROBABLE PROJECT COMPLETION DATE: 7/81

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 79-80	$ 28,830	DOE
FY 80-81	$ 24,240	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The photoelectric properties of amorphous silicon films deposited by the pyrolytic decomposition of silane will be studied in order to evaluate the performance of this material in photovoltaic cells. Hydrogenated amorphous silicon used in photovoltaic cells is normally deposited with RF assistance in a glow discharge or is sputtered in a hydrogen-containing atmosphere. Substrate temperatures ranging from 100 to 450 C permit the incorporation of approximately 10 percent hydrogen into the growing film, in the form of SiH, SiH_2, and SiH_3 complexes.

Working for the past year under the Department of Energy's support on the photothermal properties of amorphous silicon, we found that this material can be deposited by the pyrolytic decomposition of silane without the assistance of an RF glow discharge. The necessarily higher substrate temperature - typically 600°C - results in a material that: (1) is anneal-stable up to crystallization at 650°C; (2) contains hydrogen in amounts less than 1%, and (3) approaches a fully connected, ideal amorphous state, as evidenced by its optical properties.

Due to the differences in the preparation parameters, this material is unlike other forms of amorphous silicon previously studied for photovoltaic applications. We therefore propose to measure those photoelectric parameters that determine the suitability of our thermally decomposed material for use in solar cells. Using our experience in stabilizing this material against crystallization by doping, we further propose to generate pn-junctions in the growing film, and to evaluate their photovoltaic properties.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Research Study of Luminescent Solar Concentrators

CONTRACT NUMBER: XS-9-8216-1

CONTRACTOR (NAME AND ADDRESS):
Owens- Illinois, Inc.
Corporate Technology
P. O. Box 1035
Toledo, Ohio 43666

TELEPHONE: (419) 247-9832

PRINCIPAL INVESTIGATOR: P. S. Friedman

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1311

PROJECT ENGINEER: Allen Hermann

CURRENT CONTRACT PERIOD:
FROM: 7/1/79 **TO:** 7/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Photovoltaic Compound Semiconductors/
Innovative Concepts

CONTRACT FUNDING:		SOURCE:
FY 79	$ 172,871	SERI
FY 80	$ 118,853	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this program is to improve the optical efficiency and stability of luminescent solar concentrators through selection of appropriate organic dyes, hosts and substrates as well as investigation of inorganic glasses and dopants. In addition, some effort will be directed toward improving the power conversion efficiency of an LSC system through selection of photovoltaic cells better matched to the output spectrum of the LSC and reduction of losses in optical coupling to the photovoltaic cell.

To meet the described objective, seven tasks have been identified: a) Study of dyes and combinations of dyes in various thin-film hosts. b) Expand the theoretical model for the plate and collector efficiencies and calculate the plate trapping and concentrating efficiencies. c) Investigate the use of inorganic glasses in large area LSC's. d) Prepare plates of various sizes, attach solar cells, measure collector efficiency and concentration and compare results to theoretical model. e) Continue the investigation of dye degration in various host systems. f) Investigate device operating temperatures and the resulting effects of device design, durability and performance. g) Update the cost and efficiency analysis; include use of cells with bandgaps higher than that of silicon.

3.2% collection efficiency has been achieved with a 5½" X 5½" LSC plate composed of two dyes in a polymeric host on a polymer substrate using a silicon solar cell. This efficiency increase (1.9% was previously measured) reflects progress in decreasing the multiple absorption and remission processes. This design also physically separates the two dye species providing better resistance to photodegradation. Luminescense apparatus has been redesigned to allow rapid determination of relative output for a variety of plate sizes. A comprehensive program for evaluation of dye stability has been implemented. Variation of host material has led to increased dye stability. Hybrid devices utilizing uranium glass substrates are being designed and temperature efficiency studies on both polymeric and glass substrates have been performed. OI is now using the SERI Brite Monte Carlo Computer Code for mid-latitude summer, direct plus-diffuse solar photen spectrum (previously to the NASA-Lewis AM-1.5 direct component power spectrum was used).

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Preparation of a-Si:H Films by Photochemical and Free Radical Initiated Vapor Deposition

CONTRACT NUMBER: XS-0-9010-5

CONTRACTOR (NAME AND ADDRESS):
Penn State University
Chemistry Dept. 152 Davey Lab.
University Park, PA 16802

TELEPHONE: (814) 865-1209

PRINCIPAL INVESTIGATOR: Fred Lampe (Dr.)

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1497

TELEPHONE: (303) 231-1497

PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:
FROM: March 1980 **TO:** March 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/
Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
81	100,000	SERI

SUMMARY:

Thin films of amorphous Si:H and related systems will be prepared from gaseous silanes using several photochemical and free-radical decomposition techniques. The various techniques to be used include multiphoton infrared laser induced decomposition, vacuum-ultraviolet photodecomposition initiated by the attack of atoms and other free radicals on silane and disilane. The thin films prepared will be studied by a variety of physical and structural characterization tools and compared to corresponding films produced by electric discharge methods. Doping of amorphous Si:H films for physical property and device analysis will also be carried out using the same photochemical and free-radical decomposition methods. The goal of the study is to determine if photochemical and free-radical induced silane decompositions will permit fabrication of amorphous Si:H-based solar cells of increased efficiency.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Photovoltaic and Strucutral Properties of a-Si:H Thin Films

CONTRACT NUMBER: XG-0-9227

CONTRACTOR (NAME AND ADDRESS):
Penn State University
265 Materials Research Laboratory
University Park, PA 16802

TELEPHONE: (814) 865-3704

PRINCIPAL INVESTIGATOR: R. Messier

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1497

TELEPHONE: (303) 231-1497

PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:
FROM: June 1, 1980 TO: June 1, 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 93,000	DOE
FY 81	$ 99,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The general objectives of this research are to understand the critical relations governing the preparation, characterization and photovoltaic properties of hydrogenated amorphous silicon (a-Si:H) thin films prepared by rf-sputtering. During the previous year's contract work the following points were established: the a-Si:H films could be anisotropically etched to reveal the film microstructure and reduce surface reflectance; the a-Si:H film microstructure could be classified according to the structure zone model; a-Si:H films which had complete monohydride H-bonding, no post-deposition, and no noticeable microstructure could be prepared in a certain region of deposition parameter space; and bombardment effects during deposition were directly related to structural and chemical characteristics of the film. As a result of this work, the photovoltaic characteristics of sputtered a-Si:H shall continue to be optimized by an iterative process between preparation conditions and film and/or device characterization in which the effect of substrate bias, substrate temperature, substrate-target spacing, inert gas species and vacuum system pressure will be examined. Film characterization shall include impurity content determination, photo response (absorption, photoluminescence, photoconductivity,. infrared and or Raman spectroscopy), and transport (conductivity) measurements. Schottky barrier structures shall be made as a diagnostic tool when necessary. Special attention shall be paid to film morphology, using a variety of techniques including the field ion microscope, and an attempt shall be made to establish correlations between morphology and hydrogen bonding.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Controlled Cadmium Telluride Thin Films For Solar Cell Applications
CONTRACT NUMBER: XJ-0-9131-1

CONTRACTOR (NAME AND ADDRESS):
The Pennsylvania State University
207 Old Main
University Park, PA 16802
TELEPHONE: (814) 455-1666 / 3704
PRINCIPAL INVESTIGATOR: M.B. Das/S.V. Krishnaswamy

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 6/1/80 **TO:** 5/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/
Emerging Materials

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 73,706	DOE
FY 80	$ 112,753	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The program objective is to fabricate and evaluate both n and p type CdTe thin films using sputtering techniques, and then to fabricate and analyze thin film homojunction and heterojunction devices.

To meet the above objective, four tasks have been identified:

a. Perform theoretical modelling and calculations to identify the limits of CdTe film systems for photovoltaic conversion efficiencies.

b. Deposit thin films of CdTe films and alloys on selected substrates and vary the film deposition conditions to optimize the film properties.

c. Characterize the films in their chemical, structural, optical and electrical parameters.

d. Fabricate p-n junction structures and cells and characterize them.

A new separate source, heated substrate, ion sputter system is coming on line.

Films produced in a former system have been n-type with electron mobilities and concentrations of 8 cm^2/v-Sec and 10^{18} respectively.

Schottky barrier cells fabricated on these films have $n \ll 1\%$.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: Theoretical and Experimental Study of Electrochemical Photovoltaic Cells
CONTRACT NUMBER: XP-9-8002-10-MOD I

CONTRACTOR (NAME AND ADDRESS):
The Pennsylvania State University
University Park, PA 16802

TELEPHONE: (814) 865-4931
PRINCIPAL INVESTIGATOR: S.J.Fonash, J. Jordon

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1369
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: Being Negotiated **TO:**

PROBABLE PROJECT COMPLETION DATE: Being Negotiated

AREA/TASK. Compound Semiconductor /Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
79	154,633	SERI
80	~156,010	SERI

SUMMARY:

The objective of the project is to study electrochemical photovoltaic cells (EPC) both experimentally and theoretically. The materials to be evaluated in EPC's are Si, CdTe, InP and Fe_2O_3.
The approach which will be used is outlined in the following tasks.

Tasks:
1. Device modelling and materials characterization for optimal choice of EPC structures.
2. Experimental studies to choose optimal redox couples, solvents, supporting electrolytes and counter-electrode materials.
3. Development of surface preparation techniques to improve stability and efficiency of EPC's.
4. Testing and evaluation of photovoltaic parameters of EPC's.
5. Analysis of electrode stability by identification of impurities in electrodes.

The current status of the program includes the following results.
Preliminary modelling of EPC reveals origin of observed I-V characteristics. Silicon EPC's evaluated various surface treatments sputtered thin films on silicon for improvement in stability. Several transition metalcomplex couples have been synthesized and are being studied in electrochemical photovoltaic cells. Stability studies are in progress for surface modified Si photoanodes.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Polycrystalline Solar Cell/Substrate Growth by Integrated Vacuum Evaporation

CONTRACT NUMBER: XS-9-8041-14

CONTRACTOR (NAME AND ADDRESS):
Perkin-Elmer Corporation
Main Avenue - MS 283
Norwalk, CT 06856

TELEPHONE: (203) 762-6916
PRINCIPAL INVESTIGATOR: Donald L. Smith

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1396
PROJECT ENGINEER: John Benner

CURRENT CONTRACT PERIOD:
FROM: 9/23/79 **TO:** 8/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Thin Film
Gallium Arsenide

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 99,000	SERI
FY 80	$ 78,295	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The goal of this project is to demonstrate the potential of integrated semiconductor/metal-substrate vacuum evaporation for producing low-cost, high-efficiency solar cells using GaAs evaporated onto a nearly lattice-matching substrate of evaporated polycrystalline iron.

The technical approach includes three tasks:

a. Baseline GaAs Schottky cell growth on single crystal GaAs,

b. GaAs solar cell growth on single-crystal Fe, and

c. GaAs solar cell growth on polycrystalline Fe.

At present, the fabrication technique for Schottky barrier cells has been established. The performance of the baseline cells is consistent from run to run. The need for a buffer layer on the Fe substrates has been identified. Epitaxy of GaAS directly on Fe has not been achieved due to the formation of low melting point eutectics during growth.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Epitaxial Zn_3P_2 Film Growth by Activated Vacuum Evaporation
CONTRACT NUMBER XS-9-8041-7

CONTRACTOR (NAME AND ADDRESS):
Perkin-Elmer Corporation
Norwalk, CT 06586

TELEPHONE: (203) 762-6916
PRINCIPAL INVESTIGATOR: Donald L. Smith

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 9/25/79 **TO:** 6/25/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:		SOURCE:
FY 79	$ 99.036	SERI
FY 80	$ 80.268	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

Perkin-Elmer is pursuing research on the vacuum deposition of zinc phosphide (Zn_3P_2), which is a very promising Emerging Material. The technique of Activated Vacuum Evaporation offers certain special capabilities (oxidation-free environment and easy control of stoichiometry) for the study of Zn_3P_2 that are not inherent in other methods. Perkin-Elmer has devised and implemented specialized equipment to support these studies.

Vacuum evaporation of the elements eliminates Zn_3P_2 evaporant synthesis, may entail lower large-scale processing costs, and introduces several process conditions which may permit n-type growth: RF activation of incident vapor, low growth temperature, Zn/P incident flux ratio control, and co-evaporation of dopant elements. Electrical-discharge activation of the incident phosphorus vapor is expected to provide both the activation energy needed to achieve a reasonable deposition rate of Zn_3P_2 and the surface energy needed for large grain growth at low temperatures.

To date the UHV Zn_3P_2 film growth system has been completed including: phosphorus safety venting, evaporation T control with isolation from r.f. interference, substrate load-lock, and growth chamber fixturing. The zinc and phosphorus Knudsen cells have been calibrated using LN_2 cooled and room temperature quartz crystal deposition monitors, and the evaporant pressures in the cells have been calculated.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Feasibility Study Of a Microwave Heating Application For Solar Cell Fabrication

CONTRACT NUMBER: XS-0-8041-16

CONTRACTOR (NAME AND ADDRESS):

Photowatt International, Inc.
2414 West 14th Street
Tempe, AZ 85281

TELEPHONE: (602) 894-9564

PRINCIPAL INVESTIGATOR: Sanjeev Chitre

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1379

PROJECT ENGINEER: Arie P. Ariotedjo

CURRENT CONTRACT PERIOD:

FROM: 9/15/79 **TO:** 6/30/81

PROBABLE PROJECT COMPLETION DATE: 6/30/81

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	94,565	SERI
80	70,924	SERI

SUMMARY:

The objectives of this contract are to investigate the applicability of microwave energy to junction formation, back surface field formation, metallization sintering and combination of these processes.

To achieve these objectives, a microwave system for solar cell fabrication was designed, constructed and investigated.

Investigations during the first eight months permitted the development of a technique capable of producing uniform heating up through 600°C. Beyond this temperature the non-uniformity was too much of a problem to fabricate reproducible devices. A subsequent redesign of the applicator has produced results which indicate a ±5% uniformity at 1100°C. These results were obtained at the equipment manufacturer's plant and are yet to be verified by Photowatt. A further modification is being made to reduce the temperature deviation. Currently it is possible to sinter evaporated Al and electrolessly deposited Ni. With the modified equipment capability it will be possible to perform all functions. When full processes are evolved, a cost analysis will be made and reported.

BEST DOCUMENT AVAILABLE

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: ELECTROHYDRODYNAMIC PROCESS FOR THE PRODUCTION OF LARGE AREA POLYCRYSTALLINE SILICON SHEET

CONTRACT NUMBER: XS-9-8041-5

CONTRACTOR (NAME AND ADDRESS):

PHRASOR SCIENTIFIC, INC.
1536 HIGHLAND AVENUE
DUARTE, CALIFORNIA 91010

TELEPHONE: (213) 357-3201

PRINCIPAL INVESTIGATOR: JOHN F. MAHONEY

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-7299

PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:

FROM: Sept. 25, 1979 **TO:** June 30, 1981

PROBABLE PROJECT COMPLETION DATE: June 30, 1981

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
1979	96,931	SERI
1980	74,755	SERI

SUMMARY:

The objective of this "Innovative Concept" Program is to demonstrate the technical feasibility of electrohydrodynamics for producing large area polycrystalline silicon sheet for application to photovoltaics.

The electrohydrodynamic (EHD) method developed at Phrasor Scientific, Inc. uses intense electric fields applied to capillary nozzles containing molten silicon material in order to generate charged liquid droplets which are accelerated to a high velocity and subsequently impact on a target substrate. Large area coverage, fast process times, and controlled thickness films are among the potential advantages of this process.

An EHD particle source compatible with molten silicon has been designed and developed. The source has been successfully tested to produce molten silicon droplet beams which have been deposited on graphite, mullite and single crystalline silicon substrates. Grain size characterization of solidified silicon droplets reveal columnar structures whose lengths are equivalent to the thickness of the quenched droplet. Due to the rapid solidification of silicon droplets on cold substrates or substrates held at 500-700°C, average grain diameters of 1-2 micron are observed with lengths exceeding 30 microns. Present investigations are directed at producing deposits on substrates held at even higher temperatures, and at controlled cooling of remelted deposits.

Date: September, 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Plasma-Assisted CVD of Fluorinated, Hydrogenated Amorphous Silicon

CONTRACT NUMBER: XS-9-8041-2

CONTRACTOR (NAME AND ADDRESS):

Plasma Physics Corp.
P. O. Box 548
Locust Valley, L.I. New York 11560

TELEPHONE: (516) 676-4513

PRINCIPAL INVESTIGATOR: John H. Coleman

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1487

PROJECT ENGINEER: E. Sabisky

CURRENT CONTRACT PERIOD:

FROM: 9/80 **TO:** 6/81

PROBABLE PROJECT COMPLETION DATE: 6/81

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:		SOURCE:
FY 80	$ 79,322	SERI
FY 81	$ 82,400	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this program is to produce low-cost, large-area solar cells by plasma-assisted CVD of fluorinated, hydrogenated amorphous silicon (a-Si:H:F). The successful combination of plasma and CVD processes would retain the significant material cost advantage of plasma-deposited amorphous silicon (a-Si:H) while utilizing the higher optical absorption coefficients and production rates available from CVD.

CVD is known to produce a-Si:H with a higher optical absorption coefficient than plasma-deposition A-Si:H. Unfortunately, the higher temperatures required for CVD of a-Si:H using silane have resulted in excessive dehydrogenation of the a-Si:H and loss in solar cell efficiency. Thus, the present program is directed to techniques for introducing H_2 into the CVD a-Si:H and to utilizing starting gases such as di-silane which dissociate and deposit by CVD at lower temperatures than does silane; thereby offering in principle CVD a-Si:H with a higher H/Si ratio and optical absorption coefficient. Also, deposition rates of plasma-deposited di-silane are reported to be 10x higher than that of silane.

Over the past year, plasma deposition equipment using a novel electrode design which is capable of operation at CVD temperatures has been used to plasma deposit p/n junction cells at low temperatures (220°C). Depletion widths of 0.38 microns and internal J_{sc} of 12ma/cm^2 were measured which were as high as any reported in the literature. Calculations of the depletion width confirmed the EXXON model relating depletion width to J_{sc} over the entire spectral band, and clearly identified depletion width and optical absorption coefficients as the basic limits to efficiency. Also, an amorphous boron layer was used to obtain Voc between 0.65 and 0.80 volts using inexpensive contacts.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Thin Film Polycrystalline Silicon Solar Cells
CONTRACT NUMBER: XZ-0-9192-1

CONTRACTOR (NAME AND ADDRESS):
Poly Solar Incorporated
2701 National Drive
Garland, TX 75041
TELEPHONE: (214) 840-1221
PRINCIPAL INVESTIGATOR: T. L. Chu

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1379
PROJECT ENGINEER: Arie P. Ariotedjo

CURRENT CONTRACT PERIOD:
FROM: 4/15/80 TO: 4/14/81

PROBABLE PROJECT COMPLETION DATE: 4/14/81

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	237,204	DOE
80	273,237	SERI

SUMMARY:

The objectives of this contract are to fabricate large area thin film silicon solar cells with AM1 efficiency of 10% or greater with good reproducibility and good yield and to assess the feasibility of implementing this process for manufacturing solar cells at a cost of less than $500/kWe (in 1980 $).

The technical approach consists of (1) the purification of metallurgical silicon, (2) the preparation of metallurgical silicon substrates, (3) the deposition of a silicon p-n junction structure on metallurgical silicon substrates, and (4) the application of grid contacts and anti-reflection coatings.

The purification of metallurgical silicon by extraction with aqua regia has reduced the concentration of iron to 400-500 ppma and the concentration of aluminum to 250-300 ppma. The substrates (7.5cm x 28 cm) prepared from aqua regia treated metallurgical silicon consist of large crystallites of many square millimeters in area, and the impurity concentration along the length of the substrate appears to be uniform. Many large area ($>30cm^2$) solar cells have been prepared by depositing n^+/p structure of various thicknesses and dopant profiles on the substrates. Heat treatment in inert and oxygen atmospheres has been found to increase the photocurrent. AM1 efficiencies of 8.8% have been obtained. Current work is directed to the optimization of the configuration of the active region of the solar cell and the passivation of grain boundaries.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Low Cost Sprayed CdTe Solar Cell Research
CONTRACT NUMBER: XS-9-8104-3

CONTRACTOR (NAME AND ADDRESS):
Radiation Monitoring Devices, Inc.
44 Hunt Street
Watertown, MA 02172

TELEPHONE: (617) 926-1167
PRINCIPAL INVESTIGATOR: Gerald Entine, PHD.

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 8/15/79 TO: 2/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/ Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	164,793	SERI
80	91,354	SERI

SUMMARY

The objectives of this program are to develop techniques to deposit films of high electrical quality cadmium telluride (CdTe) by spray pyrolysis and to utilize these techniques to produce thin film solar cell structures having at least 3% AM1 conversion efficiency.

To meet the above objectives, the following tasks must be addressed:

1) Synthesis of an appropriate water soluble Te compound (B - $TeMe_2I_2$).
2) Assembly and optimization of the spray pyrolysis apparatus.
3) Deposition of CdS and CdTe films onto suitable substrates and studies of post-deposition treatments.
4) Formation and optimization of the p-n junction and back contact.
5) Materials and solar cell measurements.
6) Studies of cell stability and degradation.

Chemically pure n-type CdTe films have been produced. This is as evaluated by X-Ray diffraction techniques.

Thin film indium tin oxide/n-CdTe/aquadag cells have been fabricated. Best cell performance to date is $\eta = 1.6\%$ without corrections.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: High Efficiency Thin Film CdTe Solar Cells
CONTRACT NUMBER: XJ-0-9133-1

CONTRACTOR (NAME AND ADDRESS):

Radiation Monitoring Devices, Inc.
44 Hunt Street
Watertown, MA 02172
TELEPHONE: (617) 926-1167
PRINCIPAL INVESTIGATOR: Gerald Entine, PHD.

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 4/1/80 **TO:** 3/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	225,407	DOE
80	204,000	SERI

SUMMARY:

The objective of this program is to develop thin film CdTe solar cells utilizing hot wall vacuum deposition techniques.

To meet the above objective, the following tasks will be addressed:
1) Deposit thin-film layers of CdTe onto selected commercial ITO-on-glass substrates.
2) Dope the films with In and Cl or I to produce low resistivity n-CdTe, and optimize the CdTe-ITO interface.
3) Fabricate p-CdTe using analogous techniques.
4) Investigate HgSe as an ohmic contact to p-CdTe.
5) Perform physical, optical, and electrical measurements on the CdTe films.
6) Fabricate and characterize CdTe solar cells.

Thin films of n-type CdTe with grain sizes greater than 1 mm have been deposited. These films have low pinhole densities and resistivities in the range of 200-300 ohm-cm. Gold Schottky barrier cells fabricated on this material show efficiencies of around 1.5% with $V_{OC} \cdot 0.3$ volts and $J_{SC} \cdot 7.85$ ma/cm^2 (active area).

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Amorphous Boron-Silicon - Hydrogen Alloys for Thin Film Heterojunction Solar Cells

CONTRACT NUMBER: XS-0-9010-6

CONTRACTOR (NAME AND ADDRESS):

RCA Corporation
P.O. Box 432
Princeton, NJ 08540

TELEPHONE: (609) 734-3244

PRINCIPAL INVESTIGATOR: Dr. A. Moore

DIRECTING ORGANIZATION AND ADDRESS:

SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401
FTS 327-1483

TELEPHONE: (303) 231-1483

PROJECT ENGINEER: E. Sabisky

CURRENT CONTRACT PERIOD:

FROM: 6/1/80 **TO:** 8/31/81

PROBABLE PROJECT COMPLETION DATE: Aug. 1982

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 81	$ 80,000	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

This program is developing a new type of thin film heterojunction solar cell utilizing an amorphous boron-silicon-hydrogen alloy (a-B:Si:H) in conjunction with the standard hydrogenated amorphous silicon (a-Si:H). The research program involves four tasks (1) the deposition of a-B:Si:H films under various conditions; (2) the characterization of the electrical and optical properties of these films; (3) the fabrication of a-B:Si:H/a-Si:H heterojunction devices; and (4) the characterization of these devices. Preliminary results indicate that the films can be made reasonably conductive $(\sim 10^{-3}\ \Omega^{-1}\ \mathrm{cm}^{-1})$ and are p-type. Moreover, the optical absorption coefficient is significantly less than that of boron-doped a-Si:H over the visible light range.

Date:

SERI

Photovoltaics AR&D Lead Center

TITLE: Amorphous Thin Films for Solar Cell Applications
CONTRACT NUMBER: XJ-9-8254-1

CONTRACTOR (NAME AND ADDRESS):
RCA Corporation
P.O. Box 432
Princeton, NJ 08540

TELEPHONE: (609) 734-3205
PRINCIPAL INVESTIGATOR: Dr. D. E. Carlson

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401
FTS 327-1483

TELEPHONE: (303) 231-1483
PROJECT ENGINEER: E. Sabisky

CURRENT CONTRACT PERIOD:
FROM: Oct 1980 **TO:** Dec 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	625,000	SERI
80	800,000	SERI
81	900,000	SERI

SUMMARY:

The objective of this program is to develop a low-cost, stable, thin film solar cell based on hydrogenated amorphous silicon (a-Si:H) with a conversion efficiency greater than 10%. The program involves five research tasks: (1) theoretical modelling of transport and defects in a-Si:H; (2) deposition and doping studies; (3) the investigation of new experimental methods for characterizing a-Si:H; (4) the fabrication of solar-cell parameters.

Recently, conversion efficiencies as high as 6.1% have been obtained in p-i-n cells with active areas of 1.1 cm^2. Moreover, p-i-n cells with efficiencies greater than 5.7% have been produced in 3 different glow discharge systems. The solar cell structure is ITO/n-i-p/stainless steel where the ITO (indium-tin-oxide) is deposited by electron-beam evaporation.

The minority carrier diffusion length has been measured for the first time in a-Si:H by means of the photoelectromagnetic effect, and typical values are ~0.1 - 0.2 μm. Similar values have been estimated from the shape of the current-voltage characteristics of p-i-n cells under illumination. Hall mobility measurements in undoped a-Si:H indicate that the mobility is thermally activated with an energy of ~0.13 eV for temperatures above ~90°C; thus, the electron transport near room temperature appears to be associated with tunneling in states near the conduction band. Line-of-sight mass spectroscopy has shown an inverse correlation between Si_xH_y groups in the discharge atmosphere and $(SiH_2)n$ groups in the a-Si:H films. Consequently, surface chemistry appears to be playing a dominant role in the deposition of a-Si:H films.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Photovoltaic Mechanisms in Polycrystalline Thin-Film Silicon Solar Cells
CONTRACT NUMBER: AC-01-79-ET-23108

CONTRACTOR (NAME AND ADDRESS):
RCA Laboratories
David Sarnoff Research Center
Princeton, NJ 08540

TELEPHONE: (609) 734-2442
PRINCIPAL INVESTIGATOR: D. Redfield

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1482
PROJECT ENGINEER: R. W. Hardy

CURRENT CONTRACT PERIOD:
FROM: 5/79 TO: 5/81

PROBABLE PROJECT COMPLETION DATE: 5/81

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	141,675	DOE

SUMMARY

The objectives of this contract are: to develop theoretical models of those solar-cell properties that can lead to fundamental limitations in cell efficiency; to analyze specifically heavy-doping effects and doping-gradient effects; to optimize solar-cell designs by use of these models; and to apply these models to anticipated grain-boundary effects in polycrystalline thin-film cells.

Both experimental and theoretical approaches are being used to elucidate and analyze the relevant properties of the materials and devices. The theory of heavy-doping (HD) effects has been revised and extended to explain several HD limitations in Si solar cells.

Experiments are under way to clarify effects of doping gradient, surface recombination, and junction depth. New approaches in both theoretical models and experimental methods are producing a new picture of grain boundary effects.

The theory of HD effects has shown (i) that errors exist in previous theories; (ii) that Auger recombination plays a major role in limiting the efficiency of conventional cells; (iii) that the physical model of the p-n junction needs revision for solar-cell diffused junctions; and (iv) that the chief limitations on efficiency of conventional cells can all be explained in a unified way.

Effects of surface recombination have been demonstrated, even in the presence of strong doping gradients. Optimized values for junction depth, diffusion profile, and surface treatments are being sought.

The physical model governing electronic properties of grain boundaries (GB) has been shown to need revision. Grain Boundaries are found to behave in almost all respects like surfaces, with pinning of the Fermi level and larger barriers in n-Si than p-Si. A number of new interpretations are emerging from this model.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Thin Film Polycrystalline Silicon Solar Cells

CONTRACT NUMBER: XS-9-8276-1

CONTRACTOR (NAME AND ADDRESS): RCA Laboratories Princeton, NJ 08540 **TELEPHONE:** (609) 734-3170 **PRINCIPAL INVESTIGATOR:** Brian W. Faughnan	**DIRECTING ORGANIZATION AND ADDRESS:** Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401 **TELEPHONE:** (303) 231-1379 **PROJECT ENGINEER:** Arie P. Arioledjo

CURRENT CONTRACT PERIOD:

FROM: 9/11/79 **TO:** 12/12/80

PROBABLE PROJECT COMPLETION DATE: 12/12/80

AREA/TASK: Advanced Silicon/ Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
78	174,087	DOE
79	184,885	SERI

SUMMARY:

The objectives of this research and development effort are to characterize and correlate the electrical and structural properties of grain boundaries in polycrystalline silicon in order to understand grain boundary mechanisms and its limitations to solar cell performance, and to study the passivation of grain boundaries by phosphorus diffusion, atomic hydrogen or other promising techniques.

The approach consists of the following tasks: (1) determination of the influence of grain boundaries on the solar cell performance; (2) development of specific techniques to characterize the structural, compositional, electrical and optical properties of polycrystalline silicon and the correlation to cell performance; (3) development of grain boundary characterization technique to separate grain boundary effects from intrinsic bulk impurity effects; and (4) development of grain boundary passivation techniques.

Techniques for grain boundary effects analysis, i.e., electron channeling, DLTS, SPV, quantum efficiency and laser scan, have been developed. A new technique to study grain boundary, laser scan in conjunction with photoconductive technique, has been developed; this method identifies barriers at grain boundaries. Recent work includes the correlation of the liquid crystal technique and laser scanning method to identify electrical activity at grain boundaries. Hydrogen passivation of grain boundaries indicates that large grain boundary barriers are significantly reduced.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Low-Cost Epitaxial Techniques for Solar Cell Fabrication
CONTRACT NUMBER: XS-9-8274-1

CONTRACTOR (NAME AND ADDRESS):
RCA Laboratories
Princeton, NJ 08540

TELEPHONE: (609) 734-3116
PRINCIPAL INVESTIGATOR: Robert V. D'Aiello

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1379
PROJECT ENGINEER: Arie P. Ariotedjo

CURRENT CONTRACT PERIOD:
FROM: 9/25/79 **TO:** 9/24/80

PROBABLE PROJECT COMPLETION DATE: 9/24/80

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
77	205,000	JPL
78	105,000	JPL
79	200,232	SERI

SUMMARY:

The objective of this work is to refine and optimize epitaxial growth techniques to several candidate low-cost silicon substrates in order to define growth technique and substrate combination which will allow the fabrication of low-cost, high efficiency solar cells.

The technical approach consists of: (1) characterization of several candidate low-cost silicon substrate materials in terms of physical, chemical, and electronic properties; (2) optimization of epitaxial growth methods to conform with the substrate characteristics which will allow the fabrication of high-efficiency solar cells; and (3) solar cell fabrication to evaluate the influence of the epitaxial growth and structure, as well as the substrate characteristics on the solar cell performance.

The required characteristics of potentially low-cost silicon substrates have been identified, and the range of growth parameters for the successful epitaxial layer growth for solar cell fabrication on such substrates has been determined. Epitaxial solar cells of practical size and configuration have been fabricated and exhibited AM1 efficiencies greater than 11%.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Research on Thin Film GaAs Solar Cells

CONTRACT NUMBER: XS-0-9002-4

CONTRACTOR (NAME AND ADDRESS):
Rensselaer Polytechnic Institute
ESE Department
Troy, New York 12181

TELEPHONE: (518) 270-6333
PRINCIPAL INVESTIGATOR: S. K. Ghandhi

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1396
PROJECT ENGINEER: John Benner

CURRENT CONTRACT PERIOD:
FROM: 3/1/80 **TO:** 2/28/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/Thin Film Gallium Arsenide

CONTRACT FUNDING:		SOURCE:
FY 79	$ 361,268	SERI
FY 80	$ 30,000	SERI
FY 80	$ 289,354	SERI
FY	$	
FY	$	

SUMMARY:

The objective of this contract is to develop the technology necessary to produce GaAs solar cells of 10% conversion efficiency in films of less than 10 microns thickness which have been deposited by metalorganic CVD on low cost substrates.

The approach requires optimization of MO-CVD process parameters for deposition of films with good structural and electrical properties on low cost substrates. Electrochemical, DLTS, SEM and other diagnostic techniques will be applied to provide definitive structural, compositional and electrical characterization. Schottky barrier solar cells will be fabricated and tested as a guage of progress.

The best cells are approximately 7.1% efficient and are of the AR coated, gold-GaAs Schottky barrier structure. A diffusion technique for producing p-n junction cells in polycrystalline GaAs is under development. Extremely abrupt, shallow junctions have been obtained in single crystal test samples.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: Novel Concepts in Electrochemical Solar Cells
CONTRACT NUMBER: XS-0-9272-1

CONTRACTOR (NAME AND ADDRESS):
Research Institute of Colorado
Drake Creekside Two, Suite 200
2625 Redwing Road
Fort Collins, CO 80526
TELEPHONE: (303) 491-8235
PRINCIPAL INVESTIGATOR: Dr. Joel DuBow

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1369
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 6/23/80 **TO:** 6/22/81

PROBABLE PROJECT COMPLETION DATE: 6/22/81

AREA/TASK: Compound Semiconductor/Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
79	190,425	SERI
80	202,198	SERI

SUMMARY:

The following concepts will be examined during the program: (1) The use of molten salts in photoelectrochemical cells employing Si and GaAs electrodes, (2) development and optimization of photoelectrochemical cells employing $MoSe_2$, GaAs, CdSe, and $CdSe_xTe_{1-x}$ semiconducting electrodes and aqueous electrolytes, (3) the utility of the minority carrier, non-equilibrium semiconductor-insulator-semiconductor model to predict the performance of these devices, and (4) economic viability of proposed systems based upon SAMICS methodology.

The five work phases of which the research program is composed include (1) electrode fabrication and characterization, (2) electrolyte preparation and characterization, (3) cell fabrication and evaluation, (4) theoretical modelling and data analysis, and (5) economic modelling.

The feasibility of energy conversion in photoelectrical system utilizing molten salt electrolytes has been demonstrated for the first time. Detailed characterization of photoelectrochemical behavior of GaAs electrodes in these electrolytes has been carried out. Studies on devices utilizing aqueous electrolytes are currently in progress. An economic analysis using the SAMICS-IPEG formalism has been carried out for GaAs and CdSe electrochemical photovoltaic cell configurations.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Development of High Efficiency Cascade Solar Cells

CONTRACT NUMBER: XM-9-8136-1

CONTRACTOR (NAME AND ADDRESS):

Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709

TELEPHONE: (919) 541-5912/737-2330

PRINCIPAL INVESTIGATOR: S. M. Bedair/J.R. Hauser

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383

PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:

FROM: 7/1/79 **TO:** 5/30/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/ High Efficiency Concentrators

CONTRACT FUNDING:

		SOURCE:
FY 78	$ 367,140	SERI
FY 79	$ 297,000	SERI
FY 80	$ 267,809	SERI
FY	$	
FY	$	

SUMMARY:

The basic objective of this work is to continue the development of high efficiency (30 percent or more) cascade solar cells initiated under Sandia Contract No. 07-7149.

Research Triangle Institute (RTI) under a SERI contract has been investigating both theoretically and experimentally the various requirements for achieving high conversion efficiencies in monolithic cascade cells, in which a low bandgap junction and high bandgap junction are fabricated on a single substrate and electrically connected by an intermediate tunnel junction. RTI under a previously Sandia-sponsored program demonstrated open-circuit voltages above 2.3 V in a seven-layer GaAs/AlGaAs two-junction structure, verifying the electrical and optical cascade action of this approach. In the existing SERI program, RTI's work has emphasized the materials development and evaluation of four candidate materials systems, namely GaAlAs/GaAs, AlGaAsSb/GaAsSb, GaAlAs/GaAsSb, and GaInP/GaInAs. In each of these systems, the top junction and tunnel junctions are fabricated in the first material indicated and the bottom junction in the second material. RTI has demonstrated the low bandgap GaAs, GaAsSb, and GaInAs junctions. The high bandgap junctions in AlGaAs (up to 1.9 eV) and AlGaAsSb (up to 1.7 eV) have been fabricated by liquid phase epitaxy and low impedance AlGaAs tunnel junctions (up to 1.9 eV) have been demonstrated. Preliminary work has also begun developing an organometallic-vapor phase epitaxy (OM-VPE) growth system to be devoted to the evaluation of the GaAlAs/GaInAs and GaAlAsSb systems. Concerning the overall device development a combined structure consisting of a GaAs bottom junction and high bandgap AlGaAs tunnel junction has been demonstrated. A major problem that remains is improving the performance of the top cell when grown on top of the highly doped layers of the connecting junction.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Development of High Efficiency Low Cost $ZnSiAs_2$ Solar Cells
CONTRACT NUMBER: XZ-0-9142-1

CONTRACTOR (NAME AND ADDRESS):
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709

TELEPHONE: (919) 629-5930
PRINCIPAL INVESTIGATOR: Dr. J.E. Andrews, Jr.

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 6/9/80 **TO:** 4/8/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/ Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	128,737	DOE
80	167,327	SERI

SUMMARY:

The objective of this program is to determine the properties and suitability of $ZnSiAs_2$ as a solar cell material. $ZnSiAs_2$ is a structural analog to the III-V semiconductors having similar electrical and optical properties. At the same time, less critical constituents are used than the III-V compounds, and thus offer more economical materials for photovoltaics.

To meet the described objective, the following specific areas are being addressed:

a. Develop organometallic-CVD deposition technique to controllably grow $ZnSiAs_2$ on low cost substrates.

b. Demonstrate controllable technique to dope $ZnSiAs_2$ both n and p-type.

c. The fabrication of Schottky barrier, heterojunction, and homojunction structures.

d. An evaluation of the suitability of $ZnSiAs_2$ for solar cells.

Both n and p-type films have been produced by deviating the stoichiometry during growth. Electron densities are typically in the 10^{15} 10^{16} cm^{-3} range with mobilities of about 25 cm^2/v-sec. Hole concentrations are 9 X 10^{17} cm^{-3} with mobilities less than one.

N-type zinc-silicon arsenide on p-type silicon: heterojunction structures have been fabricated. AM1 cell parameters of V_{oc}-0.4V Jsc-0.64 ma/cm^2 and ff-0.31 have been achieved.

A zinc-silicon-arsenide homojunction structure has been fabricated.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Development of Polycrystal GaAs Solar Cells

CONTRACT NUMBER: XS-9-8032-1

CONTRACTOR (NAME AND ADDRESS):
Rockwell International
Electronics Research Center
P. O. Box 1085
Thousand Oaks, CA 91360
TELEPHONE: (805) 498-4545
PRINCIPAL INVESTIGATOR: Stanley Zehr

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1396
PROJECT ENGINEER: John Benner

CURRENT CONTRACT PERIOD:
FROM: 1/15/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Thin Film Gallium Arsenide

CONTRACT FUNDING:

FY	$	SOURCE:
79	866,640	SERI
80	147,380	SERI

SUMMARY:

The technical objective of this program is to: 1) develop potentially low-cost, thin film polycrystalline GaAs solar cells with 10% conversion efficiency; 2) identify the mechanisms by which grain boundaries limit cell performance; and 3) investigate material passivation and cell fabrication techniques and solar cell designs which minimize the adverse effects of grain boundaries.

The approach encompasses measurements of the electronic properties of grain boundaries, development of a practical model of the effects of grain boundaries on solar cell performance and identification and evaluation of potential chemical passivants.

The internal electric fields in the vicinity of grain boundaries have been measured by laser scanning and Auger potential profiling techniques. The density of states, at the grain boundary has been measured by DLTS techniques. Forward I-V characteristics carried out on arrays of diodes have shown that while not all grain boundaries effect the diode performance those that do result in excess leakage current in the forward characteristics. This data has been explained in terms of a model in which the Fermi level is pinned by localized bandgap states and the resulting band bending causes a double depletion region in the bulk material. At low doping levels, the leakage current consists of recombination currents. At higher dopings, the narrower depletion region enhances the probability of thermally assisted tunneling resulting in a larger effective n-value.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Chemical Vapor Deposition of Thin-film Polycrystalline Si for Low-cost Solar Cells

CONTRACT NUMBER: DE-AC03-79ET23045

CONTRACTOR (NAME AND ADDRESS):
Rockwell International
Electronics Research Center
3370 Miraloma Avenue
Anaheim, CA 92803
TELEPHONE: (714) 632-3634
PRINCIPAL INVESTIGATOR: Ralph P. Ruth

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-7299
PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:
FROM: 7/23/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
76	306,113	JPL
79	237,300	DOE

SUMMARY:

The objective of this program is to develop thin-film polycrystalline Si solar cells on low-cost substrate materials. The polycrystalline Si films used for these cells are prepared by chemical vapor deposition (CVD) techniques, and the required junctions/barriers are formed by doping during film growth or by subsequent thermal diffusion or other suitable methods.

The program has emphasized a study of the transport properties of both p-type and n-type polycrystalline Si films as functions of average grain size and impurity doping concentration. Preliminary investigations of nucleation and early-stage growth phenomena in such films provide improved understanding of the fundamental properties of the films that limit photovoltaic performance.

The study of transport properties has involved preparation of sets of B-doped p-type and P-doped n-type polycrystalline films grown simultaneously by SiH_4 pyrolysis in H_2 on polycrystalline high-purity alumina substrates in a range of average grain sizes ($\sim 1\ \mu m$ to $\sim 125\ \mu m$) and with a range of impurity doping concentrations from $\sim 10^{15}$ to $>10^{20} cm^{-3}$, primarily at 985°C.

Films have been characterized in detail by measurements of transport properties as a function of sample temperature in the range 77-420°K. The results confirm many of the features of the grain-boundary trapping model for conduction in polycrystalline Si, including the existence of a mobility minimum for an impurity doping concentration varying in magnitude with average grain size, the existence of barriers in the grain boundaries with heights that are a function of doping concentration, and a strong dependence of free carrier concentration on the impurity doping concentration. The measurements have brought out aspects of transport in polycrystalline Si not previously examined, such as the dependence of the area density of traps in the grain boundaries upon impurity doping cencentration and average grain size in the film. High atomic surface mobility during film growth has been utilized to induce clustering of Si at mechanically disturbed regions in regularly spaced nuclei leading to growth of enlarged-grain polycrystalline films. Sets of both polycrystalline and single-crystal films have been used for the fabrication of solar cells, utilizing both vapor-grown and P-diffused junctions. The CVD-grown experimental solar cell structures (using SiH_4 pyrolysis in H_2) have had poor photovoltaic properties.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Advanced Photovoltaic Concentrator Cells

CONTRACT NUMBER: XJ-9-8058-2

CONTRACTOR (NAME AND ADDRESS):

Rockwell International Electronics
Research Center
P. O. Box 1085
Thousand Oaks, CA 91360

TELEPHONE: (805) 498-4545 ext. 145

PRINCIPAL INVESTIGATOR: Stanley Zehr

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383

PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:

FROM: 8/28/79 **TO:** 10/28/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/
High Efficiency Concentrators

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 242,401	SERI
FY 80	$ 360,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this project is to demonstrate monolithic, stacked multibandgap solar cells having 30% conversion efficiency at 30°C and 25% conversion efficiency at 150°C under 500-1000 SUN AM2 illumination.

To meet the described objective, the following tasks will be performed:

1. Growth and optimization of single junction AlGaAs cells having bandgaps of 1.6eV and 1.7eV and GaAlSb cells having bandgaps of 0.95eV and 1.1eV.

2. Development of techniques for joining these optimized single junction cells by means of non-lattice matched ohmic intercell contacts having sufficiently high optical transparency combined with low electrical and thermal resistance to meet the overall performance objective.

3. Characterization of the performance of the individual cells and stacked combinations using appropriate light and dark I-V and photoresponse measurements over the operating temperature range of 30-200°C and for illumination levels of 1-1000 SUNs AM2.

Some of the accomplishments to date are:

1. Successful growth of the AlGaAsSb subcells by LPE. Open-circuit voltages as high as 0.35V, 0.55V and 0.66V were achieved at 1 SUN, ~ 200 SUNs and ~ 1000 SUNs respectively.

2. Successful growth of the AlGaAs subcells by MO-CVD.

3. Demonstration of the intercell bonding between GaAs and GaSb using intermediate layers of elemental Al and Sb. By heating sufficiently, complete alloying occurs to form an AlGaAsSb interface region which has good optical transparency for the low bandgap junction and good lattice grading.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Polymer-Semiconductor Junctions for Solar Cell Applications
CONTRACT NUMBER: XS-9-8041-1

CONTRACTOR (NAME AND ADDRESS):
Rockwell International Electronics Research Center
P. O. Box 1085
Thousand Oaks, CA 91360
TELEPHONE: (805) 498-4545
PRINCIPAL INVESTIGATOR: Jim Harris

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 9/15/79 **TO:** 9/14/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 98,931	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY

The goal of this program is to investigate the barriers formed between the metallic polymer, $(SN)_x$ and GaAs and Si and their application to low cost terrestrial photovoltaic devices.

Electrical measurements have indicated that $(SN)_x$ acts as an extremely electronegative metal forming higher Schottky barriers to n-type semiconductors than any of the elemental metals. $(SN)_x$-GaAs Schottky barrier solar cells have exhibited open circuit voltages greater than 0.7 V compared to 0.5 V for Au-GaAs cells, i.e., a 40% enhancement. A similar enhancement has been demonstrated for $(SN)_x$-Si barrier cells.

$(SN)_x$ is significantly enhanced for solar applications by incorporation of BR which shifts the reflectivity characteristics to be virtually non-reflective over the entire visible spectrum. This should improve the short circuit current of solar cells. To date, initial bromination experiments have attacked the GaAs under the $(SN)_x$ and caused the film to separate. Further experiments are planned with a controlled BR vapor pressure.

Future work will focus on polycrystalline materials to see if the use of a polymer will significantly reduce the higher excess forward leakage currents and lower open circuit voltages commonly observed in metal Schottky barriers formed to polycrystalline GaAs and Si.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Gallium Arsenide Peeled Film Solar Cells
CONTRACT NUMBER: XS-0-9002-2

CONTRACTOR (NAME AND ADDRESS)
Rockwell International
Electronics Research Center
P. O. Box 1085
Thousand Oaks, CA 91360
TELEPHONE: (805) 498-4545
PRINCIPAL INVESTIGATOR: Dr. David Miller

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1396
PROJECT ENGINEER: John Benner

CURRENT CONTRACT PERIOD:
FROM: 3/15/80 TO: 3/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Thin Film Gallium Arsenide

CONTRACT FUNDING:

FY	$	SOURCE:
80	225,000	SERI

SUMMARY:

The goal of this program is to determine the technical merit and cost feasibility of basic process steps involved in the fabrication of GaAs peeled film solar cells. Several approaches to cell growth, bonding the cell, separating the cell from the reusable substrate, and processing methods will be investigated. The solar cell performance goal of this program is to demonstrate a 15% efficient peeled film GaAs cell using a process selected on the basis of potential for production of the peeled film cells at the lowest cost per kilowatt of power produced by the cells.

The technical approach of this program is to grow GaAs solar cells on AlGaAs parting layers having AlAs content from 50% to 100%. The etch rate and preference ratio of various etchants will be evaluated as a function of parting layer thickness and aluminum content. Bonding and handling techniques will be developed for processing the thin film GaAs solar cells. The electrical and optical properties of complete solar cells, bonded to low cost substrates, will be characterized. Finally the feasibility of process scale-up and estimated cell costs will be evaluated.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Electrodeposition of Device Quality Semiconductor Materials
CONTRACT NUMBER: XS-0-9010-7

CONTRACTOR (NAME AND ADDRESS):
Rockwell International
1049 Camino Dos Rios
P. O. Box 1085
Thousand Oaks, CA 91360
TELEPHONE: (805) 498-4545
PRINCIPAL INVESTIGATOR: Dr. D. M. Tench

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 4/1/80 TO: 4/1/81

PROBABLE PROJECT COMPLETION DATE: 4/1/81

AREA/TASK: Compound Semiconductor /Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
80	97,316	SERI

SUMMARY:

The objective of this work is to prepare device quality electrodeposited thin films of CdTe and GaAs.

In the proposed program considerable attention will be devoted to system choice, electrolyte purity, electrolyte mass transport, potential distribution, temperature effects and perturbation choice. Various deposition systems will be evaluated using steady state and transient electrochemical methods and a.c. impedance techniques. Electrodeposition will be performed on polycrystalline and single crystal substrate. Electrodeposits will be evaluated and characterized by Hall and conductivity measurements, scanning electron microscopy, x-ray diffraction and photoelectrochemical measurements.

Personnel shortfalls subsequent to the contract award have caused a considerable lack of progress. Electrodeposition experiments for GaAs and CdTe are now getting underway.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Electrochemical Photovoltaic Cells: Stabilization and Optimization of II-VI Semiconductors

CONTRACT NUMBER: XG-0-9276-1

CONTRACTOR (NAME AND ADDRESS):

Rockwell International
1049 Camino Dos Rios
Thousand Oaks, CA 91360

TELEPHONE: (805) 498-4545

PRINCIPAL INVESTIGATOR: Dennis Tench

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 4/15/80 **TO:** 4/14/81

PROBABLE PROJECT COMPLETION DATE: 4/14/81

AREA/TASK: Compound Semiconductor/Photoelectrochemistry

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 199,337	SERI
FY 80	$ 219,833	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this program is to develop new electrolyte redox systems and electrode surface modifications which will stabilize the II-VI compounds against photodissolution without seriously degrading their performance in electrochemical solar cells.

The approach which will be used includes applying electrochemistry, synthetic chemistry, and materials characterization in concert to evolve a practical compromise between the interfacial chemistry and the device characteristics. This involves: a) preparation of new redox systems; b) development of synthetic procedures for modifying CdX electrode surfaces; c) preparation of mixed II-VI electrode materials; d) evaluation of the photoelectrochemical properties of II-VI electrodes, with and without surface modifications, in various redox electrolytes; e) characterization of the chemical and electrical properties of II-VI electrode materials before and after use as photoanodes; and f) comparison of electrochemical and Schottky barrier cells based on II-VI materials.

The current status of the program includes the following observation: CdSe/methanol/ferro-ferricyanide has been identified as a promising photoelectrochemical system. Langmuir film transfer appears to be a good approach to chemically modifying CdX electrode surfaces. Various Langmuir films have been explored for their potential in stabilizing cadmium chalcogenide photoanodes in aqueous electrolytes. Polypyrrole films have been electrodeposited on CdSe and GaAs semiconductor surfaces and have been shown to significantly stabilize these materials in aqueous electrolytes and have been shown to be conducting. Polycrystalline CdSe and CdSe$_x$Te$_{1-x}$ films as photoanodes have been characterized in the methanol/ferro-ferricyanide system.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Fundamental Studies of Grain Boundary Passivation in Polycrystalline Silicon With Application to Improved Photovoltaic Devices

CONTRACT NUMBER: DS-0-9109-01

CONTRACTOR (NAME AND ADDRESS):

SANDIA Laboratories
Albuquerque, NM 87115

TELEPHONE: (505) 264-9168/8863

PRINCIPAL INVESTIGATOR: C. H. Seager/D. L. Ginley

DIRECTING ORGANIZATION AND ADDRESS:

SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7299

PROJECT ENGINEER: Joseph Milstein

CURRENT CONTRACT PERIOD:

FROM: Feb 1, 1980 **TO:** Jan 31, 1981

PROBABLE PROJECT COMPLETION DATE: Jan 31, 1981

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	150,000	DOE
80	256,900	SERI

SUMMARY:

The object of the program is to investigate whether polycrystalline silicon can be a good solar cell material provided the grain boundaries are passivated. Successful passivation and use of polycrystalline silicon requires understanding of transport and recombination at grain boundaries; a major emphasis is therefore placed on basic studies of electronic transport properties in the presence of grain boundaries.

Passivation is achieved by the introduction of atomic hydrogen to the grain boundaries. Fundamental studies are carried out by a variety of scanning techniques including voltage probes and electron beam induced currents (EBIC) which allow the properties of a single grain boundary to be measured. The resulting grain boundary conductance, capacitance and recombination are related to microscopic properties of the boundary (such as density of states) by a theoretical treatment.

The single grain boundary measurements have been shown to be consistent with a simple theoretical description of grain boundary electronic structure. This model, the double depletion layer/thermal emission (DDL/TE) approach, characterizes the band bending near the grain boundary by a simple symmetric pair of depletion layers, one on either side of the grain boundary plane. The transport properties of this structure are calculated using thermionic emission expressions for current flow over, into, and out of the traps at the grain boundary center. Extensive calculations of the capacitance and conductance have been made, and the agreement observed with experimental measurements of these quantities as a function of frequency, d.c. bias, and temperature is good. Hydrogen passivation of silicon grain boundaries has been investigated and shown to be an effective means for improving the photovoltaic properties of polycrystalline silicon. Grain boundary impedance measurements made in conjunction with EBIC techniques have been used to show that the density of grain boundary trapping centers can be substantially reduced by exposures to hydrogen plasmas in a commercial ion-etching engine. Work is underway to optimize this trap removal process and to demonstrate that, when properly applied, it can have substantial impacts on the efficiencies of polycrystalline silicon photovoltaic cells.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Low Cost Silicon Process Development - Phase IV: Process Improvement
CONTRACT NUMBER: XS-9-8279-1

CONTRACTOR (NAME AND ADDRESS):
J.C. Schumacher Company
580 Airport Road
Oceanside, CA 92054
TELEPHONE: (714) 433-1663
PRINCIPAL INVESTIGATOR: Edward B. Moore

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-7299
PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:
FROM: 6/1/79 **TO:** 2/27/81

PROBABLE PROJECT COMPLETION DATE: 2/27/81

AREA/TASK: Advanced Silicon
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE
77	139,139	JPL
78	69,139	JPL
79	210,443	SERI
80	155,131	SERI

SUMMARY:

The objective of this program is to demonstrate the feasibility of a continuous closed-loop tribromosilane process for the production of solar grade silicon. In order to achieve this objective, the continued operation of the experimental mini-plant is proposed to obtain sufficient operating data and to explore process improvement opportunities. The program also includes basic research study of the tribromosilane decomposition reaction rate and order to gain better understanding of this key process step.

The technical approach to be pursued consists of four tasks, which include: (1) process improvements by operation of the mini-plant under various conditions; (2) determining the reaction rate and order of tribromosilane decomposition; (3) performing heat and material balances to characterize steady state operation, and selecting "best" process conditions; and (4) assessing economic viability of the "best" process conditions.

Over the past year, under the SERI program, efforts have been placed to optimize and integrate the individual process steps in a complete, operational mini-plant. The design of the experimental mini-plant has been completed and the construction is under-way. In order to fully exploit the potential of this technology, and thus to show the potential of meeting the DOE goals, further studies are needed to improve product yield and process economics through mini-plant investigation of improved chemistry. For process improvement, kinetic study of the product reaction is needed to support attempts in improving the reactor design.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Direct Coupled Microwave Thermal Processing for Photovoltaic Device Fabrication
CONTRACT NUMBER: XS-9-8041-15

CONTRACTOR (NAME AND ADDRESS):
Siltec Corporation
Research and Development Division
3717 Haven Ave.
Menlo Park, CA 94025
TELEPHONE: (415) 365-8600
PRINCIPAL INVESTIGATOR: David Guidici

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1379
PROJECT ENGINEER: Arie P. Ariotedjo

CURRENT CONTRACT PERIOD:
FROM: 9/25/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	99,207	SERI

SUMMARY:

The study addresses the application of microwave heating to the fabrication of solar cells. The objective of this program is to develop and demonstrate a microwave thermal processing technology which will sharply reduce the process cycle time and the energy requirements for the diffusion and metallization steps in semiconductor photovoltaic device fabrication.

A microwave furnace capable of both diffusion and metallization was designed, built, and tested. Static and dynamic profiling were used to optimize system efficiency. Junction diffusion using spin-on dopants and sintering of screened metal contact pastes was investigated. Processed wafers were characterized and solar cells were fabricated. Technical feasibility and process cost savings are yet to be demonstrated.

An operative microwave system has been designed and constructed. Static profiling has shown uniform heating at low temperatures. The major problem encountered has been in achieving diffusion temperatures. Above 860°C reradiation and corona discharge have prevented further heating. Attempts are being made to overcome this problem.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Casting of Sheet Silicon for Photovoltaic Cells
CONTRACT NUMBER: XS-0-9010-8

CONTRACTOR (NAME AND ADDRESS):
Solamat, Inc.
885 Waterman Avenue
East Providence, RI 02914
TELEPHONE: (401) 438-6784
PRINCIPAL INVESTIGATOR: M.C. Narasimhan

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1371
PROJECT ENGINEER: Thomas Surek

CURRENT CONTRACT PERIOD:
FROM: 9/80 **TO:** 9/81

PROBABLE PROJECT COMPLETION DATE: 9/81

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE
80	99,990	SERI

SUMMARY:

This program investigates the production of polycrystalline silicon sheet by casting directly from the melt. The objective is to establish the process parameters which lead to optimum silicon sheet properties (mechanical, chemical, structural and electrical) suitable for fabricating low-cost, high efficiency solar cells.

The optimization of the casting process involves investigation of parameters such as nozzle geometry, gap size and location, surface velocity or wheel rotation speed, melt temperature, and pressure. The dependence of sheet thickness, width and grain size on the process parameters will be determined.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Direct Casting of Sheet Semicrystalline Silicon
CONTRACT NUMBER: XS-9-8041-4

CONTRACTOR (NAME AND ADDRESS):
Solarex Corporation
1335 Piccard Drive
Rockville, MD 20850
TELEPHONE: (301) 948-0202
PRINCIPAL INVESTIGATOR: William F. Regnault

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-7299
PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:
FROM: 9/15/79 TO: 9/14/80

PROBABLE PROJECT COMPLETION DATE: 9/14/80

AREA/TASK: Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 99,260	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY

The object of this research is to demonstrate the formation of sheet silicon for photovoltaic cells by the technique of ambit casting. In this method a mold is brought into contact with molten silicon and a silicon film is grown on the surface.

The technical approach to be pursued consists of five tasks, which include: (1) formulating an experimental plan, encompassing the definition of equipment, materials, characterization techniques, experimental schedule, and range of process parameters; (2) developing a mathematical analytical model of the thermal environment of the mold and the semicrystalline silicon sheet; (3) assembling and calibrating equipment; (4) carrying out a series of experimental castings; and (5) characterizing and evaluating the semicrystalline sheet silicon produced as to physical, chemical and electrical characteristics.

Over the past year, the experimental plan was formulated, a thermal analysis was performed, a casting apparatus was assembled and operated, experimental castings were made, and characterization of cast semicrystalline sheet silicon is being performed. The mold material of choice has been found to be graphite, growth of sheets under thermal transient conditions has been demonstrated and a report of characterization results is expected shortly. It has been found that grains ranging in area up to 5 mm^2 could be grown. Crystallographic measurements have demonstrated that most grains are heavily twinned.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Investigation of the Impurity Tolerance of Semicrystalline Silicon Solar Cells

CONTRACT NUMBER: XS-9-8272-1

CONTRACTOR (NAME AND ADDRESS):

Solarex Corporation
1335 Piccard Drive
Rockville, MD 20850

TELEPHONE: (301) 948-0202

PRINCIPAL INVESTIGATOR: George Storti

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
FTS 327-7299

TELEPHONE: (303) 231-7299

PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:

FROM: Sept. 15, 1979 **TO:** Oct. 31, 1980

PROBABLE PROJECT COMPLETION DATE: Oct. 31, 1980

AREA/TASK: Advanced Silicon/ Polycrystalline Silicon

CONTRACT FUNDING:		SOURCE:
FY 78	$ 149,339	DOE
FY 79	$ 368,489	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

This program is designed to provide a scientific basis for understanding the relationship between the key parameters for the formation of cast polycrystalline silicon material, utilizing a mixture of metallurgical (MG) and semiconductor grade (SG) silicon as a feedstock, and the resulting photovoltaic material characteristics.

Four tasks have been identified to meet the program goals:

(1) Design and assemble a casting station to allow the reproducible and in situ casting of polysilicon ingots by unidirectional solidification.
(2) Prepare and characterize a uniform feedstock of metallurgical grade silicon, and perform experimental castings using various ratios from 0 to 10% MG to SG silicon under various thermal solidification conditions.
(3) Fabricate solar cells to characterize the material electrically and use these results to direct later casting experiments.
(4) Perform theoretical and experimental investigations of grain and grain boundary effects to relate the structural and electrical characteristics of polysilicon solar cells.

Forty-seven casting runs have been performed including MG silicon percentages of 0, 1, 5, and 10%, and solidification rates of 1, 2, and 5 cm/hr. Grain size typically increased from bottom to top of the ingots varying from approximately 0.5 mm at the bottom to 1.5 mm at the top of the casting. Maximum efficiencies of 11.1% AMO (nearly 13% AM1) were obtained for cells fabricated on wafers from 100% SG ingots. Average cell efficiencies decreased from approximately 10% AM1 (100% SG silicon) to less than 5% AM1 at 10% MG silicon levels. Typically, cell efficiencies were best on wafers taken from the top of the ingot, middle cells were next, and bottom cells were the lowest. Cell efficiencies were degraded by low short-circuit current primarily due to a reduced minority carrier diffusion length within the grains and by grain boundary recombination to a smaller extent for cells made on bottom wafers. Further loss in efficiency resulted from the domination of the dark I-V characteristics by a large space-charge component which degrades the fill factor and open-circuit voltage. Grain and grain boundary effects have been studied using photoresponse scanning, Deep Level Transient Spectroscopy, SEM, electron channelling, x-ray diffraction, and x-ray topography. Scanning photoresponse patterns have been matched with x-ray topographs to show the effect of the microstructural features (dislocations, inclusions, sub-grain boundaries and twin traces) on the photoresponse. Decreases in photoresponse at grain boundaries are attributed to the dislocation content at the boundary interface (which changes with the position of the boundary) needed to make up a portion of the mismatch between adjacent grain orientations.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Thin Film Gallium Arsenide Solar Cell Research

CONTRACT NUMBER: XS-0-9002-3

CONTRACTOR (NAME AND ADDRESS):

Southern Methodist University
Dallas, TX 75275

TELEPHONE: (214) 692-3024

PRINCIPAL INVESTIGATOR: Shirley S. Chu

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1396

PROJECT ENGINEER: John Benner

CURRENT CONTRACT PERIOD:

FROM: 3/1/80 **TO:** 2/28/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Thin Film Gallium Arsenide

CONTRACT FUNDING:

FY	$	SOURCE:
79	185,740	SERI
80	12,000	SERI
80	194,554	SERI

SUMMARY:

The objective of this research is to produce GaAs solar cells of 10% conversion efficiency in films of less than 10 micrometers thick which have been deposited by CVD on graphite or tungsten coated graphite substrates.

The principal approach used in this program is the deposition of gallium arsenide films on low-cost substrates by the reaction of gallium, hydrogen chloride, and arsine in a hydrogen flow system. Tungsten coated graphite has been used as the substrate for the deposition of gallium arsenide films. The MOS approach has been used for thin film gallium arsenide solar cells. Subsequent to the deposition process, the gallium arsenide film was oxidized in-situ with oxygen at 200°C. In some cases, the in-situ oxidation was followed by oxidation with water vapor at room temperature. A gold or silver film of 60-100 Å thickness was evaporated onto the surface to form the Schottky barrier, and the silver grid contact was also formed by evaporation. The use of a thin layer of higher energy gap material, gallium phosphide or aluminum arsenide at the surface of gallium arsenide film has been under investigation with the objective of increasing the open-circuit voltage of the MOS device. The antireflection coating will be carried out by depositing titanium dioxide, tantalum pentaoxide, or other oxides by the ion beam coating technique.

The characteristics of thin film polycrystalline solar cells of the MOS structure are: $V_{OC} = 0.65V$, $J_{SC} = 19.0\ mA/cm^2$, fill factor = 66% for an efficiency of 8.1%. The cells are $9\ cm^2$ in area using a film thickness of approximately 20 microns.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Thin Film Cadmium Telluride and Zinc Phosphide Solar Cells

CONTRACT NUMBER: XZ-0-9286

CONTRACTOR (NAME AND ADDRESS):
Southern Methodist University
Dallas, TX 75275

TELEPHONE: (214) 692-3014
PRINCIPAL INVESTIGATOR: Ting Chu

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 8/11/80 **TO:** 6/10/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 140,730	DOE
FY 80	$ 130,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The objectives of this project are to conduct research and development of thin film polycrystalline cadmium telluride and zinc phosphide solar cells on low cost substrates and to demonstrate the feasibility of producing thin film cells with a conversion efficiency of 10% or higher.

The technical approaches consist of the chemical vapor deposition of cadmium telluride and Zn_3P_2 films on graphite and coated graphite substrates, the control of conductivity type and carrier concentration in deposited cadmium telluride films, the characterization of electrical and structural properties of cadmium telluride films, and the fabrication and characterization of MOS type thin film cadmium telluride solar cells.

P-type cadmium telluride films 20 μm thick have been deposited on tungsten/graphite, bismuth/tungsten/graphite, lead/tungsten/graphite and lead telluride/tungsten/graphite substrates. Elemental antimony was used as a dopant. Resistivities in the range of 3×10^3 ohm-cm have been obtained with grain sizes up to 20 μm.

1 cm^2 Schottky barrier cells fabricated on these films have $\eta \sim 1.5\%$ with best cell parameters of 350 mV V_{OC}; 15 mA/cm^2 J_{sc} and ff of 40%.

Zinc phosphide films, as identified by x-ray-diffraction, have been deposited on ceramic coated steel substrates. The films are p-type with resistivities ranging from 150 to 250 Ω-cm; hole mobilities of 1-2 cm^2/V-sec and carrier concentrations in the 10^{15} - 10^{16} cm^{-3} range.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: Cadmium Sulfide/Copper Ternary Heterojunction Cell Research

CONTRACT NUMBER: XJ-9-8010-1

CONTRACTOR (NAME AND ADDRESS):
Sperry Univac
P. O. Box 3525
St. Paul, MN 55165

TELEPHONE: (612) 456-3163

PRINCIPAL INVESTIGATOR: D. L. Fleming

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 1/8/79 **TO:** 3/8/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
78	193,500	SERI
79	201,000	SERI

SUMMARY:

The objective of this research is the development of an 8% efficient heterojunction device consisting of cadmium sulfide and copper indium selenide. To achieve this objective, the CuInSe$_2$ films are being vacuum deposited using flash evaporation or dual source, CuInSe$_2$ and Se, coevaporations. Film electrical properties are being studied as a function of deposition conditions. Devices are being fabricated and the efficiencies achieved related to film properties.

Stoichiometric, single phased CuInSe$_2$ films have been formed using flash evaporation and dual source evaporation. Neither system has given films having reproducible electrical properties. The factors affecting CuInSe$_2$ properties are being studied at this time. Devices of 6 cm^2 area and nearly ½% efficiency have been made. Low short curcuit current has been the major deficiency of these devices. Further work in this are will not be supported with Sperry Univac beyond the current contract period.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Amorphous Silicon Solar Cells by Ion Implantation

CONTRACT NUMBER 03-79-ET-23042

CONTRACTOR (NAME AND ADDRESS):

Spire Corporation
Patriots Park
Bedford, MA 01730

TELEPHONE: (617) 275-6000

PRINCIPAL INVESTIGATOR: Dr. A.R. Kirkpatrick

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1370

PROJECT ENGINEER: Jack Stone

CURRENT CONTRACT PERIOD:

FROM: 1/79 TO: 1/80

PROBABLE PROJECT COMPLETION DATE: 1/80

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	123,500	DOE

SUMMARY:

The goal of this project is to improve the conversion efficiency of solar cells formed by ion implantation of amorphous silicon. Specifically the following will be addressed:

a. Deposit CVD thin polycrystalline silicon films and convert to amorphous form by implanting silicon, argon, or hydrogen.

b. Develop doping processes for a-Si films by addition of dopant gases to SiH_4 CVD or by ion implantation of boron and phosphorus.

c. Establish the Si-H bonding system by hydrogen implantation.

d. Investigate the effects of pulsed electron beam heating to improve the properties of the films.

e. Characterize the films as to structure, optical, and electronic properties.

f. Evaluate the material by preparing Schottky and p-n junction solar cell structures.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Preparation of Germanium-on-Silicon Substrates for Gallium Arsenide Solar Cells by Electron Beam Processing

CONTRACT NUMBER: XS-0-9002-1

CONTRACTOR (NAME AND ADDRESS):
SPIRE Corporation
Patriots Park
Bedford, MA 01730

TELEPHONE: (617) 275-6000
PRINCIPAL INVESTIGATOR: S. P. Tobin

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1396
PROJECT ENGINEER: John Benner

CURRENT CONTRACT PERIOD:
FROM: 3/15/80 TO: 3/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Thin Film Gallium Arsenide

CONTRACT FUNDING:		SOURCE:
FY 80	$ 164,260	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY

The goal of this research is to develop pulsed electron beam processing techniques for heteroepitaxial growth of graded alloys of silicon and germanium on silicon wafers. This Si/Ge transition region will provide a high quality germanium surface for use as a substrate for GaAs solar cells.

The technical approach includes the following:

a) Modeling of the melting, regrowth and resulting properties of the Ge/Si transition region,

b) Deposition of Ge or Ge/Si alloys on silicon substrates,

c) Optimization of the electron beam pulse parameters to achieve a single crystal Ge surface, and

d) Characterization of the structural, compositional and electrical properties of the transition region Si/Ge alloy.

Analysis of the Ge-Si lattice mismatch problem has concluded that continuous alloy grading from Si to Ge will not reduce dislocation densities to tolerable levels in these thin films. Abrupt compositional steps are more effective in stopping dislocation propagation and are more appropriate to this structure. Initial evaporated Ge films did not adhere to Si when pulsed; contamination is suspected, and an improved evaporation process has been tried. CVD films had no adhesion problems and were successfully melted and recrystallized by the electron beam; no data are available yet on crystalline quality. Heavy Ge implants into Si were also electron-beam pulsed, resulting in good crystallinity and expected alloy compositions of up to 75 percent Ge.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Investigation of Photoelectrochemical Corrosion of Semiconductors

CONTRACT NUMBER: XG-9-800-2-6-MOD I

CONTRACTOR (NAME AND ADDRESS):

SRI International
333 Ravenswood Avenue
Menlo Park, California 94025

TELEPHONE: (415) 326-6200

PRINCIPAL INVESTIGATOR: Dr. K.W. Frese, Jr.

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 4/15/80 **TO:** 4/14/81

PROBABLE PROJECT COMPLETION DATE: 4/14/81

AREA/TASK: Compound
Semiconductor /Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
79	116,713	SERI
80	136,425	SERI

SUMMARY:

The objective of this project is to study the influence of defects such as dislocations and grain boundaries on the photoelectrochemical corrosion of GaAs, CdTe, and Si. Additionally, redox couples and surface pretreatments will be sought that suppress such corrosion.

The approaches which will be used include:

a) Measure corrosion rates on ideal single crystals.
b) Produce defective single crystals with dislocations and surface steps. Obtain polycrystalline material to measure grain boundary effects.
c) Measure and compare corrosion rates on ideal and defective surfaces.
d) Vary redox levels in solution to alter competition between corrosion and hole exchange with solution.
e) Look for redox couples that stabilize defective surfaces.
f) Corrosion measurements will be made with the rotating ring-disc electrode.
g) A theoretical modeling of decomposition potentials for defective surfaces.

The current status of the program includes the following accomplishments:

- The effects of concentration, pH, and light intensity on the stabilization efficiency were studied for Fe(II) EDTA and hydroquinone on well-etched GaAs.

- The effect of fractional monolayers of deposited noble metals as stabilizing agents on GaAs was investigated and a strong effect observed.

- Dislocations were introduced by lapping GaAs, and the stabilization efficiency was measured as a function of concentration of reducing agent. The results clearly demonstrated that defective surfaces are much harder to stabilize: the more defective a surface, the lower its corrosion stability.

- Various redox couples are tried to determine which would effectively suppress the photocorrosion of GaAs. The best results were obtained with Fe(II) citrate, Fe(II) EDTA, and hydroquinone. The latter two stabilizing agents were the easiest to detect on the ring-disc electrode. Stabilization efficiency was > 99% for Fe(II) EDTA.

- A theory of decomposition potentials at defects was developed and applied to GaAs. The model showed that the decomposition potential becomes more negative as more bonds at a defect site are broken. According to the thermodynamic theory of corrosion of semiconductors, a more negative decomposition potential implies that a stronger reducing agent is needed for stabilization.

- A model was developed showing that a thin protective layer of SiO_2 (thin enough for tunneling) forms and that a steady state is reached in which electron transfer balances the tendency to further oxidation.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: ELECTROCHEMICAL CHARACTERIZATION OF POLYCRYSTALLINE THIN FILMS FOR SOLAR CELLS

CONTRACT NUMBER: XG-0-9307

CONTRACTOR (NAME AND ADDRESS):

SRI International
333 Ravenswood Avenue
Menlo Park, Calif. 94025

TELEPHONE: (415) 326-6200 x3868

PRINCIPAL INVESTIGATOR: S. Roy Morrison

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-7299

PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:

FROM: July 23, 1980 **TO:** July 27, 1981

PROBABLE PROJECT COMPLETION DATE: July 27, 1981

AREA/TASK: Advanced Silicon/ Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
1979	98,331	DOE
1980	104,412	SERI

SUMMARY:

The objective of this investigation is to use the techniques of semiconductor electrochemistry to characterize grain boundaries and dislocations in silicon. Thin layers of polycrystalline semiconductors will undoubtedly be used for practical solar cells. Good methods of characterizing such layers are needed now for research, and, later, for quality control. Because of the difficulties associated with the grain boundaries in interpreting conductance or photoconductance measurements parallel to the layers, it is concluded that studies of the Schottky barrier, where the voltage is applied normal to the layer, provide the most promising technique for easy measurement of diffusion length, dopant density, and the properties and density of active grain boundaries in the layer.

The measurement of capacity/voltage and current/voltage using an electrochemical Schottky barrier, rather than a metal/semiconductor Schottky barrier, has many advantages. It is non-destructive and easy to apply. Current flow can be blocked by using an indifferent electrolyte, so that grain boundary leakage currents are minimized and the space charge capacity is monitored easily. Finally, current flow can be induced at will by introducing active ions for studies of grain boundary leakage. Thus, for example, such characteristics as conducting bands in the grain boundaries can be detected by noting the energy level of ions in solution that can exchange carriers with these bands.

The program is in two parts. One is the generation of recipes for electrolyte solutions that can be used for reliable measurement of doping level and diffusion length. The second is the study of current flow between certain ions in solution and grain boundaries, where such current flow will be used to characterize the grain boundaries in terms of their deleterious effect on solar cell performance. At the present time apparently reliable techniques have been developed for L_p and doping level measurement, but further tests are needed. Significant current flow associated with grain boundaries is noted, and conceivably one could use the magnitude of the current to monitor the perfection of the layers. However, the understanding of the origin of the current is incomplete, and research is underway to understand in more detail the relation between current flow and film quality.

Date: September 1980

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SERI

Photovoltaics AR&D Lead Center

TITLE: Sprayed CdS/CuInSe$_2$ and Sintered CdTe Low-Cost Solar Cells

CONTRACT NUMBER: XS-9-8104-4

CONTRACTOR (NAME AND ADDRESS): SRI International Menlo Park, CA **TELEPHONE:** (415) 326-6200 x 2906 **PRINCIPAL INVESTIGATOR:** John Mooney	**DIRECTING ORGANIZATION AND ADDRESS:** Solar Energy Research Institute 1617 Cole Boulevard Golden, CO 80401 **TELEPHONE:** (303) 231-1383 **PROJECT ENGINEER:** Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 9/1/80 **TO:** 2/28/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	173,309	SERI
80	113,226	SERI

SUMMARY:

The objectives of the proposed continuation effort include: (1) continuation of the development and characterization of chemically sprayed CdS, CuInSe$_2$ and Cd$_x$Zn$_{1-x}$S films and sintered layers of CdS and CdTe; (2) continuation of analysis of thermodynamics, chemical kinetics, and device physics of the various layers and junctions; (3) development and characterization of solar cells formed by chemical spray and sintered film techniques with an analysis of the mechanisms which control the photocurrent and junction rectification and limit the photovoltaic efficiency.

In order to meet the above objectives the four following areas need to be addressed:

1) Fabricate solar cell devices using p-CuInSe$_2$/CdS and p-CuInSe$_2$/Cd$_x$Zn$_{1-x}$S layers formed by spray pyrolysis.

2) Fabricate devices from sintered CdS and CdTe layers.

3) Characterize the above layers with reference to chemical, physical and electrical properties.

4) Characterize the above devices electrically in order to optimize the output.

Spray pyrolysis cadmium sulphide films with a resistivity of 2 Ω-cm have been deposited. An all sprayed CdS/CuInSe$_2$ heterojunction has been fabricated. This device had V_{oc} - 0.33 V and J_{sc} - 0.25 mA/cm^2 at 150 mW/cm^2. A study of basic thermodynamic influences on film growth has been completed yielding significant improvements in CuInSe$_2$ film quality.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Fundamental Studies of Photocarrier Tunneling in GaAs Thin Film Solar Cell Structures

CONTRACT NUMBER: XI-9-8030-1

CONTRACTOR (NAME AND ADDRESS):

Stanford University
Stanford, CA 94305

TELEPHONE: (415) 497-4680

PRINCIPAL INVESTIGATOR: G. L. Pearson

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1396

PROJECT ENGINEER: John Benner

CURRENT CONTRACT PERIOD:

FROM: 3/19/79 **TO:** 3/18/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/Thin Film Gallium Arsenide

CONTRACT FUNDING:

FY	$	SOURCE:
79	84,454	SERI

SUMMARY:

The objective of this contract is to increase the efficiency of heterojunction Schottky barrier solar cells by optimizing minority carrier (photocarrier) transport mechanisms.

The technical approach in this project consists of the following:

a. Identify the role that carrier tunneling plays in p-n heterojunction transport.

b. Identify the role of minority carriers in transport at a Schottky barrier.

c. Fabricate Schottky barrier solar cells optimized for minority carrier transport.

Analysis of p-n heterojunctions which were fabricated with tunneling as the primary transport mechanism has shown that heterojunction grading reduces the effect of the hole barrier on device performance.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Photoelectronic Properties of Zinc Phosphide Crystals, Films, and Heterojunctions

CONTRACT NUMBER: XJ-9-8031-1

CONTRACTOR (NAME AND ADDRESS):
Stanford University
Dept. of Materials Science
and Engineering
Stanford, CA 94305
TELEPHONE: (415) 497-2951
PRINCIPAL INVESTIGATOR: Dr. Richard H. Bube

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 2/26/80 **TO:** 1/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	109,013	SERI

SUMMARY:

The purpose of this research program is to investigate the photoelectronic properties of zinc phosphide (Zn_3P_2) in single crystal form, in thin-film form, and in heterojunctions in which Zn_3P_2 forms one of the elements. This research is directed toward understanding the role of crystalline defects and impurities in Zn_3P_2, the nature of the electronic charge transport in single crystal and thin-film material, and the properties of photovoltaic heterojunctions involving Zn_3P_2.

Enhanced nucleation and faster transport rate were confirmed after pre-growth baking of the quartz ampoule in vacuum was carried out to reduce the residual gases in the ampoule during growth. Enhanced growth rate of single crystal Zn_3P_2 was also achieved by using iodine as a chemical transport agent. Both source and crystal growth temperatures could be reduced while maintaining the growth rate. Electrical measurements of the chemical-transport grown Zn_3P_2 indicate p-type conductivity of about the same magnitude at 300°K as in crystals grown by sublimation in the sealed tube method, thus indicating that iodine does not play an appreciable role as donor impurity.

The effect of heat treatment of Zn_3P_2 in different atmospheres was investigated. Heat treatment in H_2 (5 min at 410°C) or Ar (40 min at 455°C) caused a reduction in resistivity, by about a factor of four in H_2 and by about 50% in Ar. Heat treatment in vacuum (5 hr at 335°C) caused the resistivity to increase to 10^5 ohm-cm. Heat treatment in oxygen (5 min at 575°C) caused the surface to become highly conducting. A surface Auger scan, a sputtered depth profile, and an Auger scan after profiling were carried out at SERI. Where oxygen is present, phosphorus is deficient, indicating ZnO formation; in the oxygen heat-treated sample phosphorus is not detectable until about 4000A into the sample. All results indicate that Zn_3P_2 is strongly susceptible to oxidation. Hydrogen annealing minimizes the oxidation of Zn_3P_2.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: MIS Solar Cells on Thin Polycrystalline Silicon
CONTRACT NUMBER XJ-0-9080-1

CONTRACTOR (NAME AND ADDRESS):
State University of New York at Buffalo
Department of Electrical Engineering
4232 Ridge Lea Road
Amherst, NY 14226
TELEPHONE (716) 831-3166
PRINCIPAL INVESTIGATOR: W. A. Anderson

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1482
PROJECT ENGINEER: R. W. Hardy

CURRENT CONTRACT PERIOD:
FROM: 3/80 TO: 3/81

PROBABLE PROJECT COMPLETION DATE: 3/81

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	60,000	DOE
80	109,400	SERI

SUMMARY

The goal of this project is to develop a low-cost Cr-MIS solar cell using thin-film (<30 μm) Si as the active semiconductor. This goal is being approached using a four-pronged attack. The studies thus involve: (1) electron-beam deposition of thin Si films; (2) materials and electrical analysis of these films; (3) fabrication and evaluation of MIS cells on various types of silicon; and (4) a study of the reliability of these MIS solar cells.

E-beam deposited Si films on a Si substrate have exhibited epitaxial type growth in that a (111) substrate produces a (111) film. Depositions at 500°C have shown good crystallinity and a fine structure. MIS solar cells fabricated on these films have a low efficiency which has been traced to large impurity content of C and Cu. These are now being eliminated. MIS cells have also been made on Wacker poly-Si, silicon on ceramic, RTR ribbon, IBM ribbon and Hamco large diameter silicon. Efficiency values range from 5% to 13% depending on substrate choice. I-V-T studies on poly-Si are being used to evaluate grain boundary effects. Reliability studies involve lead bonding, encapsulation, light bias studies and environmental effects on encapsulated cells.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Fabrication and Testing of MIS Solar Cells on Amorphous Si:F:H

CONTRACT NUMBER: XS-9-8041-9

CONTRACTOR (NAME AND ADDRESS):
State University of New York - Buffalo
Department of Electrical Engineering
4232 Ridge Lea Road
Amherst, NY 14226

TELEPHONE: (716) 831-3166

PRINCIPAL INVESTIGATOR: Dr. Wayne Anderson

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1483

PROJECT ENGINEER: E. Sabisky

CURRENT CONTRACT PERIOD: FROM: 9/80 TO: 6/81

PROBABLE PROJECT COMPLETION DATE: 6/81

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 54,109	SERI
FY 81	$ 52,346	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The purpose of this program is to fabricate and test low cost hydrogenated amorphous silicon solar cells. This project is being approached by analysis and design considerations of a-Si:H solar cell operation. Design consideration involves understanding the effects of three components of thin film solar cells; the a-Si:H film, the substrate and thin metal films as a top electrode. Analysis of the device is made to identify the current collection mechanism and to find the cause of the discrepancy between the theoretical limit and experimental results.

Three different types of a-Si:H films, I-N, P-I-N and N-I-P, have been deposited on the substrates, Mo, Cr, stainless steel and Al, under various deposition conditions. Various metals such as Cr, Al, Pd, Cu, Ag and Hf have been deposited on a-Si:H films. More than 80 a-Si:H films have been evaluated.

P-N junction a-Si:H solar cells show better performance than the Schottky structure due to a higher inherent built-in-potential. Furthermore, the open circuit voltage (V_{oc}) of N-I-P structures is 20-30% higher than V_{oc} of P-I-N structures. Low work function metal (Cr, Al, Cu) produce larger V_{oc} in N-I-P structures than does the higher work function metal (Pd). Fill factor (FF) is almost independent of the choice and resistivity of the thin metal electrode. A Mo substrate results in a higher FF than does the more widely used stainless steel. Design considerations have produced a short circuit current density (J_{sc}) of 7.5 mA/cm^2 and V_{oc} of 750 mV on large area cells by the deposition of the inexpensive metal (Cr). $V_{oc} > 800$ mV and FF > 0.5 were produced separately on other cells.

Device analysis is performed to develop a computer simulation model for photovoltaic performance. Our model predicts a 5% efficiency on Cr -N-I-P- Mo with a slight change of thickness of the N-layer. A 20-30% increase of J_{sc} is expected by decreasing the thickness of the top layer from 300 Å to less than 100 Å without causing any changes of V_{oc} and FF. Our goal of 5% will be reached with J_{sc} = 10 mA/cm^2, V_{oc} = 800 mV and FF = 0.6.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Investigation of Nonaqueous Regenerative Photoelectrochemical Cells

CONTRACT NUMBER: XG-0-9178-1

CONTRACTOR (NAME AND ADDRESS):
SumX Corporation
1300 E. Braker Lane
P. O. Box 14864
Austin, TX 78761
TELEPHONE: (512) 835-0330
PRINCIPAL INVESTIGATOR: Dr. David DeBerry

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1369
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 4/15/80 **TO:** 4/14/81

PROBABLE PROJECT COMPLETION DATE: 4/14/81

AREA/TASK: Compound Semiconductor/Photoelectrochemistry

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 136,587	SERI
FY 80	$ 147,423	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The object of the proposed program is the characterization of the behavior of semiconductors in nonaqueous solvent/redox couple systems which are potentially usable in regenerative(liquid junction) photoelectrochemical cells (PECs) and the minimization or elimination of the degradation processes which inherently limit cell performance in terms of stability and efficiency. Such an effort requires the investigation and optimization of electrolytes and semiconductors. Enhanced stability may also allow modifications to obtain higher energy conversion efficiencies.

Three principal tasks form the basis of this study; these tasks are: (1) semiconductor/solvent screening; (2) second stage screening in the presence of redox couples; and (3) efficiency and extend degradation tests. Task 1 involves the determination of the key characteristics of approximately 50 combinations of n-type semiconductors and aprotic solvents. Task 2 will characterize approximately ten of the most favorable combinations from Task 1 when coupled with redox systems. Task 3 will involve determining the solar energy conversion efficiencies for approximately three of the most favorable semiconductor/solvent.redox systems. Extended stability testing and efficiency sensitivity will also be examined in Task 3.

The following accomplishments have been attained in the program:
Halide ions influence dark reductions on n-WSe_2 and n-$MoSe_2$ samples with defects or "edges." Treatment with chloride ion can increase the performance of such n-WSe_2 samples for photooxidation of thianthrene in acetonitrile.

Promising survey results have been obtained using p-WSe_2 for photoreduction or organic species in acetonitrile. Photoreduction of nitrobenzene can occur with an open circuit voltage of 0.9 V and high concentration of reactant.

Cells constructed using n-WSe_2 for photooxidation of bromide ion or chloride ion acetonitrile electrolytes show efficiencies of 6 to 10%; chloride cells showed apparent stability during chlorine production.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: Cadmium Sulfide/Copper Sulfide Heterojunction Cell Research
CONTRACT NUMBER: XJ-9-8033-2

CONTRACTOR (NAME AND ADDRESS):
Telic Corporation
1631 Colorado Ave.
Santa Monica, CA 90404
TELEPHONE: (213) 828-7449
PRINCIPAL INVESTIGATOR: John A. Thornton

DIRECTING ORGANIZATION AND ADDRESS:
SERI/Photovoltaic Programs Office
1617 Cole Blvd.
Golden, CO 80401
TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 9/15/80 TO: 9/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/ Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
79	149,504	SERI
80	317,582	SERI

SUMMARY:

Objective:
To investigate and evaluate the application of cylindrical-post magnetron reactive sputtering for the production of solar cell quality thin films of Cd(Zn)S/Cu_2S for large-scale terrestrial photovoltaic energy conversion.

Approach:
The approach can be described in terms of the following tasks:

1) A modification of the deposition apparatus to overcome several deficiencies identified during a previous program.
2) An investigation of the use of In doping to control the resistivity of the Cd(Zn)S layer.
3) An investigation of the use of off-stoichiometric deposition or post deposition heat treatment to control the resistivity of the Cd(Zn)S layer.
4) An investigation of the optimum method for depositing the Cu_2S layer.
5) An investigation of all sputter deposited Cd(Zn)S/Cu_2S solar cell structures formed on glass substrates.
6) Interact with subcontractors (Institute of Energy Conversion and Lockheed) to develop hybrid cell using sputtering and evaporation methods.

Status:
Coatings are being deposited by reactive sputtering from metal targets (Cu, Cd, Cd doped with In and/or Zn) in an Ar-H_2S working gas. Cd(Zn)S resistivity control has been demonstrated using both In doping and off-stoichiometric deposition (pulsed H_2S flow). Photovoltaic response has been demonstrated in cells formed with both In doped and off-stoichiometric Cd(Zn)S. Low efficiencies (< 1%) have resulted because of non-optimum Cu_xS layers. The deposition of Cu_xS over CdS is currently under investigation. The use of high Cd(Zn)S deposition temperatures has been shown to cause a deleterious interaction between the Cd(Zn)S and Nb base electrode. Hybrid cells with efficiencies of 1.6% have been fabricated.

BEST DOCUMENT AVAILABLE

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Fabrication of Monocrystalline GaAs Solar Cells Utilizing Sacrificial NaCl Substrates

CONTRACT NUMBER: XS-0-9002-5

CONTRACTOR (NAME AND ADDRESS):
United Technologies Research Center
East Hartford, CT 06108

TELEPHONE: (203) 727-7498

PRINCIPAL INVESTIGATOR: A. J. Shuskus

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1396

PROJECT ENGINEER: John Benner

CURRENT CONTRACT PERIOD:
FROM: 5/15/80 **TO:** 5/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Thin Film Gallium Arsenide

CONTRACT FUNDING:

FY	$	SOURCE:
80	209,000	SERI

SUMMARY:

The objective of this project is to establish a process technology for fabrication of low cost, high efficiency thin film monocrystalline GaAs photovoltaic cells suitable for application in terrestrial or satellite power systems. The goal of the program in the first year is to achieve a cell conversion efficiency of 10 percent or greater employing a GaAs film thickness of less than 10 microns.

Germanium is deposited on the NaCl substrate followed by deposition of molybdenum on the Ge to provide strength after separation from the NaCl. Techniques for separation and handling of the Ge film will be developed. The germanium film will be cleaned and used as a substrate for fabrication of thin single crystal GaAs solar cells.

At present, free standing single crystal films of germanium, 1 cm^2 in area and 10 microns thick, have been prepared. Germanium deposition process parameters have been refined to the extent that films of good quality can be produced consistently. Hall data on free-standing germanium films shows a carrier concentration in the range of 5×10^{15} to 1×10^{16} cm^{-3}, n-type, with a carrier mobility of approximately 900 cm^2/V sec.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Integrated Material/Device Approach for Cu_2S/CdS Solar Cells

CONTRACT NUMBER: XS-0-9010-9

CONTRACTOR (NAME AND ADDRESS):
University of California at Los Angeles
School of Engineering and Applied Sciences
Los Angeles, CA 90024

TELEPHONE: (213) 825-2210

PRINCIPAL INVESTIGATOR: Rointan Bunshah

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 4/1/80 **TO:** 3/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE:
80	99,959	SERI

SUMMARY:

The main objective of the proposed program is to develop a low cost integrated materials/solar cell approach for fabrication of Cu_2S/CdS thin film solar cells. The approach comprises: 1) investigating the preparation and properties of Cu_2S, CdS films of controlled stoichiometry by the Activated Reactive Evaporation (ARE) process; 2) investigating the fabrication, characterization and optimization of thin film Cu_2S/CdS solar cells in a cell geometry which overcomes many of the degradation effects commonly encountered in such cells prepared by conventional techniques. The ARE process would also allow the fabrication of solar cells in a sequential all vacuum process.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE The Development of a Measurement System for Resistivity of Thin Semiconductor Films on Metal Plates

CONTRACT NUMBER XS-9-8197

CONTRACTOR (NAME AND ADDRESS)

University of Colorado
Dept. of EE at Denver
Denver, CO 80202

TELEPHONE

PRINCIPAL INVESTIGATOR F.S. Barnes/D.S. Gage

DIRECTING ORGANIZATION AND ADDRESS:

SERI
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 321-1361

PROJECT ENGINEER: Philip R. Pierce

CURRENT CONTRACT PERIOD:

FROM 6/79 TO 9/80

PROBABLE PROJECT COMPLETION DATE: 8/81

AREA/TASK

Technical Support/Measurement and Evaluation

CONTRACT FUNDING:

FY	$	SOURCE:
79	86,361	SERI
80	20,500	SERI

SUMMARY

This contract will improve the accuracy and speed of the resistivity measurement of thin semiconductor films which have been deposited on metal plates.

The measurement is made by observing the change in the Q of a resonant microwave cavity: the Q of the cavity is measured with and without the presence of the semiconductor film. The actual Q measurements can be made using either a slotted line or a pair of directional couplers. Both methods are being investigated. The entire measurement process is being automated using TI 9900 microcomputer system. The software control for this microcomputer is being written in BASIC for ease of transfer to other computing systems.

Instrument optimization has been delayed due to a very noisy millimeter - wave source coupled to the 100,000 + Q test cavity. Instrument investigation has shown that high noise enables the test cavity to find some r-f energy at the resonant frequency of the cavity and give erroneous results. The Impatt source is being replaced with a Gunn diode source after extensive millimeter wave source reviews.

Completion of the automation package will be realized after incorporation of the new millimeter-wave source.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Diagnostics of a Glow Discharge Used to Produce Amorphous Silicon Films

CONTRACT NUMBER: XJ-0-9053-1

CONTRACTOR (NAME AND ADDRESS):
University of Colorado
JILA
Boulder, CO 80309

TELEPHONE: (303) 492-7841

PRINCIPAL INVESTIGATOR: A. Gallagher (Dr.)

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Boulevard
Golden, CO 80401
FTS-327-1497

TELEPHONE: (303) 231-1497

PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:

FROM: Feb 1980 **TO:** Feb 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/Amorphous Materials

CONTRACT FUNDING:

FY	$	SOURCE:
80	99,000	SERI

SUMMARY:

A. Gallagher and J. Scott, at the University of Colorado, are diagnosing the discharges used to produce hydrogenated amorphous silicon films. They are instrumenting a flowing gas discharge to measure the plasma electrical properties, and the species and radiation emitted from the discharge. These observations will be used to deliniate the parameters and processes which control the resulting properties of the deposited films.

In addition to the gas chemistry, the role of impurities, surface bombardment, surface reactions, and discharge parameters will be studied. They plan to use these observations to develop models for the dominant discharge chemistry and electron collision processes. The resulting models and understanding can be used to develop more economic and effective methods of film production from glow discharge.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Grain Boundary Effects in Photovoltaics

CONTRACT NUMBER: DE-AC01-79ET23105

CONTRACTOR (NAME AND ADDRESS):
University of Delaware
Newark, DE 19711

TELEPHONE: (302) 738-8701

PRINCIPAL INVESTIGATOR: J. W. Edington

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369

PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:

FROM: 1/80 **TO:** 12/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductors/Cadmium Sulfide

CONTRACT FUNDING:

		SOURCE:
FY 80	**$** 67,348	DOE
FY	**$**	
FY	**$**	
FY	**$**	
FY	**$**	

SUMMARY:

The objective of this program is to determine the influence of known grain and low angle boundary structure in CdS, Cu_2S and Zn_3P_2 on photovoltaic conversion efficiency.

To meet the desired objectives well defined boundaries will be generated and characterized in bicrystals and their influence on minority carrier losses by recombination and trapping determined. These bicrystals will be treated to develop CdS/Cu_2S and Zn_3P_2/Nb, Be or Al junctions using microelectronic techniques and the influence of grain boundaries on barrier heights measured. In addition, the influence of interface dislocation density at the CdS/Cu_2S heterojunction on photovoltaic conversion efficiency will be determined. Finally the electrical properties of the various grain and low angle boundaries will be correlated with the defect structure in terms of existing theories. To date bicrystals with the desired misorientations have been prepared by sintering and grain boundary structures have been determined.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Theory of Thin Film Photovoltaics

CONTRACT NUMBER: DC-AC-01-79ET-23103

CONTRACTOR (NAME AND ADDRESS):
University of Delaware
Newark, DE 19711

TELEPHONE: (303) 738-8048
PRINCIPAL INVESTIGATOR: Karl W. Boer

DIRECTING ORGANIZATION AND ADDRESS:
SERI/Photovoltaics Programs Office
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 4/16/80 **TO:** 4/15/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductors/
Cadmium Sulfide

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 52,108	DOE
FY 80	$ 54,500	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

Objective: The physics of the photovoltaic effect shall be further developed and applied to thin-film solar cells with the objective to identify important experimental parameters and their optimum range, to prepare means to measure, monitor and adjust such parameters in order to provide guidance to obtain solar cells with improved cost efficiency. A limited amount of experiments will be used to check key elements of the proposed theory.

Approach: The proposed theory will make use of a detailed analysis of transport and Poisson equations of both carriers in an asymmetric homo- or heterojunction, with the aim to obtain from the shape of current-voltage characteristics important device material parameters. An attempt will be made to reduce the complex mathematical model to a workable bench-type model. The new model will be judged according to its usefulness to guide researchers towards cell optimization.

Results Achieved: Neglecting a modifying resistive network and parallel interconnection of microdiodes with different properties, it was obtained from a detailed analysis of transport and Poisson equation:

1. Deviation from the ideal current-voltage characteristic require substantial junction (interface) recombination.
2. Such deviations can be classified as to specific differences in shape.
3. Several classes of characteristics can be used to identify junction parameters.
4. When the junction interface recombination velocity exceeds 10^6 cm/s, the shape of the characteristics yield directly the level distribution from its slope and bias voltage.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE Physical Models for Thin-Film Polycrystalline Solar Cells Based on Measured Grain-Boundary and Electronic Parameter Properties
CONTRACT NUMBER XS-9-8275-1

CONTRACTOR (NAME AND ADDRESS):
University of Florida
Electrical Engineering Department
Gainesville, FL 32611
TELEPHONE (604) 392-4929
PRINCIPAL INVESTIGATOR F. A. Lindholm

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1482
PROJECT ENGINEER: R. W. Hardy

CURRENT CONTRACT PERIOD:
FROM 9/79 TO: 11/80

PROBABLE PROJECT COMPLETION DATE 11/80

AREA/TASK Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
78	130,000	DOE
79	122,227	SERI

SUMMARY

The objectives of the research are: (i) to identify and characterize the basic photovoltaic mechanisms that govern the conversion efficiency of thin-film polycrystalline solar cells; (ii) to experimentally determine the electronic parameters related to these photovoltaic mechanisms; and (iii) to relate these mechanisms and parameters to the conversion efficiency through theoretical physical models developed for engineering design. These models would enable informed design choices to be made to improve cell efficiency.

The approach involves combined theoretical and experimental efforts. The dominant photovoltaic mechanisms are identified from experimental results from solar cells and test structures made from single-crystal and polycrystalline silicon. Theoretical modelling produces analytic descriptions where possible, but relies on numerical solutions for guidance where necessary.

Experimental efforts seeking improvement in conversion efficiency through passivation or removal of grain boundaries are in progress. Methods of determining parameters describing surface states of grain boundaries are being sought. Correlations of the electrical activity of grain boundaries with structure and chemistry are being pursued. Experimental results to date are consistent with theoretical predictions of dark and illuminated current-voltage characteristics and their temperature dependences. Experiments have identified the importance of the previously unrecognized recombination mechanisms in the p-n junction space charge region. This mechanism was first suggested by theoretical models. Phenomenological heavy doping effects have been experimentally described in sufficient detail to provide practical guidance for design of solar cells and processes. Experimental parameters have been determined which are sensitive to grain boundaries and their electrical activity. For example, the ambipolar grain-boundary surface recombination velocity, a parameter of central importance in the theoretical modelling, has been determined by analysis of the low-voltage portion of the current-voltage behavior of test structures. Intragrain lifetime has been determined using three independent methods: I-V characteristics, x-ray induced short-circuit current, and EBIC. Complete agreement between the three methods was obtained.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Low Cost Solar Cells Based on Amorphous Silicon Electrodeposited from Organic Solvents

CONTRACT NUMBER: HS-0-9045-1

CONTRACTOR (NAME AND ADDRESS):

University of Southern California
University Park
Los Angeles, California 90007

TELEPHONE: (213) 741-6224

PRINCIPAL INVESTIGATOR: F.A. Kroger

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1370

PROJECT ENGINEER: Jack Stone

CURRENT CONTRACT PERIOD:

FROM: 11/79 **TO:** 10/80

PROBABLE PROJECT COMPLETION DATE: 10/80

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 54,824	DOE
FY 80	$ 15,311	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The goal of this project is to develop the electrodeposition process to produce amorphous silicon solar cells. The approach necessary to achieve the project objectives consists of the following tasks:

a. Select appropriate electrolytes, current densities, and deposition potentials for electrodeposition of amorphous silicon on nickel, stainless steel, oxide-coated glass, or plastic sheet covered with thin gold film.

b. Characterize the structure, composition, and electrical properties of the silicon films.

c. Determine the deposition conditions necessary for doping the plated silicon films.

d. Fabricate Schottky barrier solar cells.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Photorechargeable Electrochemical Solar Cells Based on Semiconductor Electrodes

CONTRACT NUMBER: XS-0-9306

CONTRACTOR (NAME AND ADDRESS):

University of Texas at Austin
Austin, Texas 78712

TELEPHONE: (512) 471-3761
PRINCIPAL INVESTIGATOR: Dr. A.J. Bard

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Dr. Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 8/1/80 **TO:** 7/31/81

PROBABLE PROJECT COMPLETION DATE: 7/31/81

AREA/TASK: Compound Semiconductor /Photoelectrochemistry

CONTRACT FUNDING:

FY	$	SOURCE:
80	59,963	SERI

SUMMARY:

Photorechargeable solar cells consisting of suitable semiconductor and metal electrodes - electrolyte solution combinations containing redox couples having potentials appropriately matched to the semiconductor energy levels will be investigated as the program objective.

Photoelectrochemical redox batteries will be developed using three possible configurations: a) n -SC/B_{red}//A_{ox}/M, b) M/B_{red}//A_{ox}/p-SC and c) n-SC/B_{red}//A_{ox}/p-SC. Possible systems will be chosen on the following criteria:

a) Band gap (E_g) of the semiconductor should not be too high . {$E_g \leq$ 2 eV for maximum efficiency (> 10%)}
b) Materials stable under illumination in the redox electrolyte.
c) Flat-band potential (V_{fb}) as negative as possible for n-type materials and as positive as possible for p-type materials.
d) Materials with appropriate doping levels (charge carrier densities $-10^{17}/cm^3$).
e) For "dual photocells", V_{fb} for p-type electrodes should be well positive of V_{fb} for n-type electrodes. The action spectra of n- and p-type electrodes should be well matched.
f) Thin films of polycrystalline materials should be applicable, if possible.

Several characteristics of redox couples are required in photorechargeable PEC cells:

a) Fast heterogeneous kinetics at semiconductor and counter electrodes during charge in the light and dark discharge at the inert (current collecting) electrodes.
b) No chemical changes in charged or discharged state on standing or after repeated cycling.
c) Couples can stabilize, or at least do not react with, the electrode surfaces.
d) Highly soluble materials with not too low equivalent weight.
e) Inexpensive, readily available materials.
f) Couples with desired redox potentials matched to semiconductor energy levels.

g) Materials are safe, non-toxic, easily disposable.

The work has just been initiated.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Investigation of Solar Cells Based on Cu_2O

CONTRACT NUMBER: XG-0-9190-1

CONTRACTOR (NAME AND ADDRESS):
University of Washington
Joint Center for Graduate Study
Seattle, WA 98195

TELEPHONE: (509) 943-3176
PRINCIPAL INVESTIGATOR: Larry C. Olsen

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 6/1/80 TO: 5/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE
79	161,522	DOE
80	122,521	SERI

SUMMARY:

The objective of this project is to investigate the photovoltaic properties of solar cells based on Cu_2O, particularly with respect to their potential for low-cost photovoltaic power conversion. Cu_2O is an attractive material for low-cost solar cells since it has a direct bandgap of 2.0 eV and because sheets of large-grain Cu_2O can be grown simply by oxidizing copper.

The focus of the current effort includes: (1) continuation of the development and characterization of controllably doped Cu_2O substrates and evaluation of alternate approaches to thin film growth; (2) development of conductive ZnO films of good optical quality for application in heterojunction devices; (3) development and characterization of greater than 1 cm^2 Cu_2O based Schottky barrier, MIS, or heterojunction solar cell structures with analysis of the mechanisms which control the photocurrent, junction rectification and limit the photovoltaic efficiency.

JCGS has demonstrated an improved short-circuit current of 8.3 mA/cm^2 and an efficiency of 1.76% using a newly developed MIS structure tentatively identified as $Cu/(CuBr)/Cu_2O$. Two current mechanisms have been identified in this structure, one approximated with a Jo equal 10^{-9} A/cm^2 and a diode factor of 1.

In addition, a $V_{oc} = 0.42$ V has been measured on a ZnO/Cu_2O heterojunction. These improvements may be attributed to an improved substrate cleaning process. Further research is necessary to develop and optimize the Cu_2O substrate preparation and doping process and to fabricate and characterize Cu_2O based solar cell structures in order to confirm their potential for achieving the DOE goals of low cost (less than \$300/peak kWe) and high efficiency.

Date: September 1980

BEST DOCUMENT AVAILABLE

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SERI

Photovoltaics AR&D Lead Center

TITLE: Materials for High Efficiency Multijunction Cells

CONTRACT NUMBER: XP-9-8081-1

CONTRACTOR (NAME AND ADDRESS):
Varian Associates, Inc.
Corporate Solid State Laboratory
611 Hansen Way
Palo Alto, CA 94303
TELEPHONE: (415) 493-4000
PRINCIPAL INVESTIGATOR: R.L. Bell/M.J. Ludowise

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 4/1/79 **TO:** 5/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/
High Efficiency Concentrators

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 365,668	SERI
FY 80	$ 221,273	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of this contract is to develop a materials technology in InGaInAs and Al InAsSb mixed crystal systems which will make available a two-gap monolithic concentrator cell with 28% or higher AM2 conversion efficiency at 500 to 1000 suns.

The proposed multigap cell structures are: (a) GaAs substrate/GaInAs graded region/GaInAs bottom cell/AlGaInAs tunnel junction/AlGaInAs top cell; and (b) InP substrate/AlGaAsSb bottom cell/AlGaAsSb tunnel junction/AlGaAsSb top cell. The most effort to date has been devoted to structure (a); although some attention has been given (b) under a DOE Basic Energy Sciences contract. Substantial progress has been made in setting up the OMVPE system and making it operational. Difficulty in achieving compositional control because of parasitic reactions between some of the reactant gases was overcome by proper selection of source species and growth conditions. Compositional control and uniformity in growth of the GaInAs graded layer is now very good, and it has been shown that the quality of the layer is related to the rate of grading. Problems still exist in controlling the doping in the fabrication of the tunnel junction. Further research needs to be carried out to verify the potential of the various materials systems for fabricating high efficiency cascade solar cells, improving the quality of the low and high bandgap p-n junctions, improving the quality of the intermediate connecting junction, improving control of the doping processes, reducing the amount of strain and defects which degrade the performance of the overall monolithic cascade cell, and demonstrating photovoltaic conversion with a goal of 25 percent efficiency at the end of the contract period.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Research on High Voltage Cells for Compact Receiver

CONTRACT NUMBER: XS-0-9010-10

CONTRACTOR (NAME AND ADDRESS):
Varian Associates, Inc.
611 Hansen Way
Palo Alto, CA 94303

TELEPHONE: (415) 493-4000 x 2906
PRINCIPAL INVESTIGATOR: R. L. Bell

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 3/1/80 **TO:** 2/28/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/High Efficiency Concentrators

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 99,795	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The study addresses the development of high voltage GaAs/AlGaAs cells for compact concentrator receiver applications. These cells, each generating of the order of 100 volts, would consist of a large number of series-connected micro-cells formed on a single chip of about 1 cm x 1 cm. The objective of this program is to fabricate these structures, to evaluate their performance with special empahsis on junction leakage and series resistance effects, and to address techniques for reducing obscuration and obtaining maximum uniformity of performance over the whole cell. At the end of the contract period, a report shall be written assessing the potential of the high voltage cell concept, and detailed technology developments needed for meeting or exceeding the DOE goal of $300/peak kWe, in single junction and multijunction forms.

During the period since the initiation of work, n-on-p organometallic (OM) layers suitable for the high voltage cell have been grown, processing of devices has begun, and a computer program to use in cell design and analysis has been developed.

Date: September 1980

BEST DOCUMENT AVAILABLE

SERI

Photovoltaics AR&D Lead Center

TITLE: InP Single Junction Concentrator Cell

CONTRACT NUMBER: RZ-0-9354

CONTRACTOR (NAME AND ADDRESS):
Varian Associates, Inc.
Corporate Solid State Laboratory
611 Hansen Way
Palo Alto, CA 94303
TELEPHONE: (415) 493-4000
PRINCIPAL INVESTIGATOR: Peter Borden

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1383
PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:
FROM: 9/29/80 **TO:** 12/28/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/
High Efficiency Concentrators

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 245,698	SERI
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The program with Varian Associates addresses the research and development of an InP-based cell in which contacting of both n and p sides of the junction is made from the heat sink side of the cell, thus eliminating the resistance losses and obscuration of front metallization fingers. InP is selected because the low front-surface recombination velocity achievable eliminates the requirement of a higher bandgap "window layer". In addition, using the borosilicate glass/InP sealing technology developed at Varian for photocathode applications allows thin single crystal films of InP to be used.

The objectives of the proposed research effort include the following: (1) evaluate, using test structures, the proper input parameters (e.g., diffusion lengths, recombination velocities, conductivities) for designing and modelling a representative concentrator cell; (2) evaluate various processing techniques for the fabrication of the back-contact cell, such as the glass-sealing operation, groove contacting, and cell/heat sink bonding; (3) fabricate and test a front contact InP concentrator cell to evaluate the high intensity operation of InP junctions and contacts; (4) fabricate and test a back contact InP concentrator cell using the inverted glass-sealed structure; and (5) investigate the advantages of the InP/InGaAsP technology for improving cell performance and easing fabrication problems.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Cd Si AS$_2$ Thin Films for Solar Cell Applications

CONTRACT NUMBER: XG-0-9143-1

CONTRACTOR (NAME AND ADDRESS):

Virginia Polytechnic Institute and
State University
Blacksburg, VA 24061

TELEPHONE: (703) 961-6693

PRINCIPAL INVESTIGATOR: Dr. L.C. Burton

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-1383

PROJECT ENGINEER: Kim Mitchell

CURRENT CONTRACT PERIOD:

FROM: 4/9/80 **TO:** 4/8/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Compound Semiconductor/
Emerging Materials

CONTRACT FUNDING:

FY	$	SOURCE:
79	140,259	DOE
80	152,051	SERI

SUMMARY:

The program objective is to develop thin film heterojunction solar cells in which the semiconductor materials are cadmium sulfide (CdS) and the chalcopyrite cadmium silicon diarsenide (CdSiAs$_2$).

The approach is based on three major tasks:

1. Growth of CdSiAs$_2$ thin films using sputtering and evaporation techniques, and film optimization.
2. Film characterization, including composition, x-ray analysis, Hall effect, absorption coefficient and minority carrier diffusion length.
3. Solar cell fabrication and measurement, using thin films of CdSiAs$_2$ and CdS.

A new three source ion sputtering machine has recently been made operable. The initial stages of machine characterization have begun using edax and optical methods to evaluate CdAs$_2$ thin films on glass.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Cuprous Oxide Photovoltaic Cells
CONTRACT NUMBER: DE-AC04-79ET 23010

CONTRACTOR (NAME AND ADDRESS): Wayne State University Detroit, Michigan 48202 **TELEPHONE:** (303) 577-3095 **PRINCIPAL INVESTIGATOR:** Dan Trivich	**DIRECTING ORGANIZATION AND ADDRESS:** Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401 **TELEPHONE:** (303) 231-1383 **PROJECT ENGINEER:** Kim Mitchell
CURRENT CONTRACT PERIOD: **FROM:** 4/9/79 **TO:** 1/31/81 **PROBABLE PROJECT COMPLETION DATE:** **AREA/TASK:** Compound Semiconductor/ Emerging Materials	**CONTRACT FUNDING:** **SOURCE:** FY 79 $ 140,675 DOE FY $ FY $ FY $ FY $

SUMMARY:

The general objective of this project is to develop low cost photovoltaic cells based on cuprous oxide (Cu_2O). Cu_2O is of interest because it is easily derived from copper which is a relatively inexpensive and highly available material and in which the U.S. is self-sufficient. At this stage, the need is to increase the conversion efficiency from the present 1% to the targeted 10%.

To meet the described objective, research efforts are concentrating on the following:

a. Improving quality of Cu_2O layer with respect to important material properties (resistivity, carrier lifetime, etc.).
b. Controllably doping the solar cell layers.
c. Fabricating and characterizing MIS and heterojunction structures.
d. Developing adequate device quality to demonstrate improved conversion efficiencies.

Results of Auger and ESCA studies verify that chemical reactions occur at the interface between Cu_2O and some metals. This is shown by the existence of Cu(0), copper metal, at the interface which forms a Cu/Cu_2O junction, thus limiting the barrier heights and the V_{oc} to those of the Cu/Cu_2O junction. An oxide interlayer may serve to prevent this reaction.

Methods were developed for the preparation of dilute Cu alloys, which, on oxidation, yield Cu_2O with a low resistivity of $\sim 100\text{-}200\ \Omega \cdot \text{cm}$. This may make it possible to eliminate the additional step of the $500^\circ C$ anneal, previously used to obtain low resistivity material. Heterojunctions have been made with CeO_2 and Sm_2O_3 on Cu_2O but the photocurrent is low because of the high resistivity of the films. A new method of measuring diffusion lengths was developed for use on Cu_2O, which has the advantage that accurate values of the absorption coefficient are not required. Good linear plots of $1/C^2$ vs V_R are obtained from which the built-in potential can be evaluated. An extension of the Wagner-Bloem model for Cu_2O is proposed to account for the effect of impurities.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Low-Cost Substrates for Polycrystalline Silicon Solar Cells by Electrodeposition Processes

CONTRACT NUMBER: XS-9-8119-2

CONTRACTOR (NAME AND ADDRESS):

Westinghouse R&D Center
1310 Beulah Road
Pittsburgh, PA 15235

TELEPHONE: (412) 256-4048

PRINCIPAL INVESTIGATOR: William R. Gass

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Blvd.
Golden, CO 80401

TELEPHONE: (303) 231-7299

PROJECT ENGINEER: Joseph B. Milstein

CURRENT CONTRACT PERIOD:

FROM: 9/79 TO: 6/81

PROBABLE PROJECT COMPLETION DATE: June 30, 1981

AREA/TASK: Advanced Silicon/ Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
79	134,095	SERI
80	121,640	SERI

SUMMARY:

The goal of this program is to identify and develop economical processes for fabricating polycrystalline silicon substrates suitable for photovoltaic applications. Studies have been initiated to evaluate the technical feasibility for producing thin-film polycrystalline silicon sheet on selected substrates by molten salt electrolytic deposition techniques. Acid leaching and electrorefining purification processes currently being developed and tested will permit the utilization of inexpensive silicon feedstocks for the electrodeposition processes.

Feasibility studies by several investigators have confirmed that polycrystalline silicon can be electrolytically deposited on a variety of electrically conductive substrate materials. This program utilizes a binary or ternary molten salt electrolyte consisting of alkali metal fluoride solvents (KF,LiF) into which are dissolved economically acceptable silicon feedstocks such as metallurgical grade (MG) silicon, potassium fluosilicate (K_2SiF_6), or sand (SiO_2). A voltage applied across the silicon containing molten salt electrolyte deposits elemental polycrystalline silicon on the cathode or negative electrode. Deposition parameters are varied to produce desired silicon crystal size and film thickness. Intentional doping of electrolytes may permit selection of p or n type silicon with desired resistivity.

Polycrystalline silicon has been electrodeposited on several different substrates including silver, tantalum, molybdenum, graphite, and nickel in film thicknesses to 200 µm and crystal diameters to 100 µm. Major and trace impurities have been identified and quantized in electrodeposited silicon films and in silicon feedstocks through analytical procedures including optical microscopy, scanning electron microscopy, energy dispersive analysis by x-ray, emission spectroscopy, and x-ray diffraction. Acid leaching and electrorefining purification processes have been and are being utilized to reduced undesired impurities one or more orders of magnitude in silicon feedstocks and in silicon deposition electrolytes. Silicon films are currently being electrically characterized and will soon be evaluated for solar cell applications.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE Investigation of Photovoltaic Mechanisms in Polycrystalline Thin Film Solar Cells
CONTRACT NUMBER XG-0-9233-1

CONTRACTOR (NAME AND ADDRESS)
Westinghouse Electric Corporation
Research and Development Center
1310 Beulah Road
Pittsburgh, PA 15235
TELEPHONE (412) 256-3394
PRINCIPAL INVESTIGATOR J. R. Szedon

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
TELEPHONE: (303) 231-1482
PROJECT ENGINEER: R. W. Hardy

CURRENT CONTRACT PERIOD
FROM: 8/80 TO: 7/81

PROBABLE PROJECT COMPLETION DATE: 7/81

AREA/TASK Advanced Silicon/
Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
78	341,426	ERDA
79	223,701	DOE
80	187,553	SERI

SUMMARY

The objective of this program is to clarify fundamental aspects of grain boundary influences on photocurrent collection and opposing current transport in polycrystalline silicon cells. Results of the program should allow better understanding of thin film polycrystalline silicon solar cells which are being considered as a means of meeting the goals of 10% efficiency or greater at a cost of $0.50 per peak watt (in 1980 dollars).

The approach used is to: (1) model the electrical effects of idealized grain boundaries on solar cell performance; (2) develop techniques of grain boundary characterization using scanned light spot evaluation and lateral sensing methods; and (3) characterize effects of a variety of barrier formation methods and plasma treatments on grain boundary behavior and solar cell performance.

A new analytic model of a columnar grain structure has been developed allowing for variable physical characteristics. This model, which incorporates a new method of solution, has reduced the number of matrix equations requiring solution by one half. It should allow for improved understanding of physical processes in polycrystalline material as well as photovoltaic device operation. The implementation of this new solution is currently hampered by problems with numerical results, which arise from the mixed boundary conditions on the cylindrical edges. A number of possible approaches have been identified to alleviate these difficulties, one of which involves a Green's function approach.

Lifetime matrix experiments in Wacker SILSO polycrystalline silicon have been carried out. Cells on Wacker SILSO material do not show strong degradation effects associated with grain boundary influences. Photocurrent suppression at grain boundaries is very weak (about 12%) in this material; values of minority carrier diffusion length are very large (~110 μm) comparing cells with base regions of various thickness (down to 50 μm). Some of the problems associated with the grain boundary insensitivity of Wacker SILSO have been circumvented by identifying correlated slices with very similar grain structures taken in sequence from the original cast ingot. Effects of plasma hydrogenation of Wacker material have been studied. Grain boundary passivation by atomic hydrogen has been demonstrated by studies of detailed photoresponse of MIS-type cell structures.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Cadmium Sulfide/Copper Sulfide Heterojunction Cell Research

CONTRACT NUMBER: XJ-9-8143-1

CONTRACTOR (NAME AND ADDRESS):
Westinghouse R&D Center
1310 Beulah Road
Pittsburgh, PA 15235

TELEPHONE: (412) 256-3394
PRINCIPAL INVESTIGATOR: John R. Szedon

DIRECTING ORGANIZATION AND ADDRESS:
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-1369
PROJECT ENGINEER: Satyen Deb

CURRENT CONTRACT PERIOD:
FROM: 9/13/80 TO: 4/12/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:
Compound Semiconductor/Cadmium Sulfide

CONTRACT FUNDING:

FY	$	SOURCE
74-76	514,100	NSF
77	170,500	ERDA
78	170,500	DOE
79	285,251	SERI
80	200,000	SERI

SUMMARY:

The objective of this program is to conduct research for developing cadmium sulfide/copper sulfide-based thin-film solar cells capable of 10 percent AM1 cell conversion efficiency with less than 5 percent degradation in performance over a useful life of 20 years.

To meet the described objective, the Westinghouse Electric Corporation will undertake a 12-month program having two major tasks: (1) to produce thin film Cu_2S/CdS solar cells of 9% conversion efficiency and document the relevant preparative details for such cells and (2) to assess the prospects of achieving a conversion efficiency of 10% or more in cells fabricated by dry, potentially low-cost processing. For the first task, involving about 80% of the program effort, this basic film preparation, processing methods and cell geometry used by the IEC group will be utilized. Preparative details will be duplicated to the fullest extent possible based on published information and such auxiliary descriptions (detailed drawings, process descriptions or private communications) as are appropriate. Relevant details of the process will be examined in light of past Westinghouse experience and capabilities with evaluative methods. Provisions will be made for direct observation of the IEC 9% conversion efficiency goal of this program.

Two meetings between the IEC and Westinghouse staffs including on site visits have taken place. Based on information obtained from the two meetings cells,with efficiencies of 7.5% have been fabricated.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Structural and Electronic Studies of Defects in Hydrogenated Amorphous Silicon

CONTRACT NUMBER: XJ-0-9079-1

CONTRACTOR (NAME AND ADDRESS):
Xerox Corporation
Palo Alto Research Center
Palo Alto, Calif. 94304

TELEPHONE: 415-494-4120

PRINCIPAL INVESTIGATOR: R. Street

DIRECTING ORGANIZATION AND ADDRESS:
SERI/PVAS
1617 Cole Blvd.
Golden, CO 80401
FTS 327-1497

TELEPHONE: (303) 231-1497

PROJECT ENGINEER: H. Mahan

CURRENT CONTRACT PERIOD:
FROM: March 80 TO: March 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Silicon/ Amorphous Materials

CONTRACT FUNDING:		SOURCE:
FY 80	$ 91,000	DOE
FY 81	$166,000	SERI
FY	$	
FY	$	
FY	$	

SUMMARY:

The aim of this program is basic research into plasma-deposited hydrogenated amorphous silicon with particular reference to the role of defects in the electronic properties. We have available a wide range of techniques for structural and electronic studies. Our research has shown that a close relationship exists between the growth morphology of the films, the hydrogen bonding and the formation of electrically active defects. Infrared spectroscopy and proton nuclear magnetic resonance are being used to determine details of the silicon-hydrogen bonding. Photoluminescence and electron spin resonance have identified the primary defect as a silicon dangling bond and have shown how the defects influence the recombination process. Research in progress is investigating the increase in defect density with doping by boron and phosphorus, and the modifications of the localized state distribution with compensation. Transport measurements of time-of-flight drift mobility and deep level transient spectroscopy and being developed. These experiments will clarify the role of defects in the transport of electrons and holes, and will determine the energy and distribution of localized states.

Date: September 1980

SERI

Photovoltaics AR&D Lead Center

TITLE: Exploratory Development of Thin-Film Polycrystalline Silicon Photovoltaic Devices

CONTRACT NUMBER: SERI RFP No. RM-0-9100

CONTRACTOR (NAME AND ADDRESS):

Currently in Negotiation with Final Competitive Range: Honeywell, RCA, and Motorola

TELEPHONE: N/A

PRINCIPAL INVESTIGATOR: N/A

DIRECTING ORGANIZATION AND ADDRESS:

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

TELEPHONE: (303) 231-7143

PROJECT ENGINEER: R. M. Moore

CURRENT CONTRACT PERIOD:

FROM: 10/80 **TO:** 9/81

PROBABLE PROJECT COMPLETION DATE: 9/81

AREA/TASK: Advanced Silicon/Polycrystalline Silicon

CONTRACT FUNDING:

FY	$	SOURCE:
80	3,000,000	SERI

SUMMARY:

Overall DOE Photovoltaics Program plans require that an advanced material/thin-film technology be ready for Technology Development by the end of FY83 and demonstrate Commercial Readiness by the end of 1990. To meet this goal, Exploratory Development was to be initiated in FY80 for technologies which have satisfied certain criteria in terms of cell efficiency, cell area, stability and low-cost potential. Based on the results demonstrated, it was determined that thin-film polycrystalline silicon has satisfied the requirements for initiating the Exploratory Development phase in FY80.

Subcontracted research will be pursued with industrial laboratories who have demonstrated expertise in the various phases of research and exploratory development of polycrystalline silicon solar cells.

The objectives for FY81 are to:

- Demonstrate > 8% cell efficiency for > 10 cm^2 area.
- Demonstrate > 100 cm^2 polycrystalline silicon sheet area.

The long-range goal is to achieve the Photovoltaics AR&D goal of transferring a thin-film materials technology to the Technology Development phase by the end of FY83. This technology will have the potential to meet a module cost goal of less than $0.50 per peak watt by 1990.

Negotiations are currently underway with the Final Competitive Range (Honeywell, RCA, and Motorola). Subcontracts will be completed during September 1980.

Date: September 1980

PHOTOVOLTAICS TECHNOLOGY DEVELOPMENT AND APPLICATIONS

The Photovoltaic Technology Development and Applications program is managed by the Jet Propulsion Laboratory under an agreement between the Department of Energy and the National Aeronautics and Space Administration (NASA).

Field organizations with implementing project responsibility include:

Sandia Laboratories

Jet Propulsion Laboratory - Photovoltaics Technology Development and Applications Lead Center

Jet Propulsion Laboratory - Low Cost Solar Array Project

Massachusetts Institute of Technology/ Lincoln Laboratory

Massachusetts Institute of Technology/ Energy Laboratories

NASA/Lewis Research Center

Active contracts are organized according to the institution with contract management responsibility and, within, alphabetically by contractor.

SANDIA NATIONAL LABORATORIES

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JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Characterization of PV Cells
CONTRACT NUMBER: 62-1523

CONTRACTOR (NAME AND ADDRESS):
A&T University Foundation
Attn: Dr. Albert Smith
P. O. Box 20366
Greensboro, NC 27420
TELEPHONE: (919) 379-9761
PRINCIPAL INVESTIGATOR: E. K. Stefanakos

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-2609
PROJECT ENGINEER: R. J. Chaffin

CURRENT CONTRACT PERIOD:
FROM: 5-31-80 **TO:** 12-31-80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Devices /4.2

CONTRACT FUNDING:

FY	$	SOURCE
80	21000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop testing methods for concentrator cells

Measurement of contractor supplied cells

DELIVERABLES:

Report

STATUS:

Final Report Due

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/22/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: 10 kW Advanced Power Conditioning Unit

CONTRACT NUMBER: 13-0306

CONTRACTOR (NAME AND ADDRESS):

Abacus Controls, Inc.
Somerville, New Jersey

TELEPHONE: (201) 526-6010

PRINCIPAL INVESTIGATOR: George O'Sullivan

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-3043

PROJECT ENGINEER: D. R. Smith

CURRENT CONTRACT PERIOD:

FROM: 2/1/79 **TO:** 12/18/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Power Conditioning and Control /2.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	118600	DOE AN-15
80	24290	

SUMMARY:

CONTRACT OBJECTIVES:

This program is for the design and construction of a 10 kW PCU of advanced design for use with utility interactive, residential photovoltaic systems. This unit will consist of a voltage-fed, two SCR inverter followed by a controlled force resonant transformer, which also uses two SCR's for amplitude control. This circuit was selected by Abacus as most likely to achieve an acceptably low cost in the near term.

DELIVERABLES:

Prototype 10 KVA PCU

Technical Report SAND80-7077

STATUS:

Breadboard design completed.

Fabrication of unit is underway.

DATE PREPARED: 9/24/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Construction of 11 kW Solar Array Simulator

CONTRACT NUMBER: 13-5170

CONTRACTOR (NAME AND ADDRESS):

Abacus Controls Inc.
Somerville, New Jersey

TELEPHONE: (201) 526-6010

PRINCIPAL INVESTIGATOR: George O'Sullivan

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-3043

PROJECT ENGINEER: D. R. Smith

CURRENT CONTRACT PERIOD:

FROM: 5-17-79 **TO:** 10-31-79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Power Conditioning and Control /2.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	32900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The purpose of this work is to design, construct, and deliver to Sandia one 11 kW solar array simulator for use in testing 10 kW power conditioning units presently being developed for photovoltaic systems.

DELIVERABLES

11 KVA Array Simulator

Technical Report

STATUS:

Complete

DATE PREPARED: 8/20/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: 75 kW Array Simulator

CONTRACT NUMBER: 46-0150

CONTRACTOR (NAME AND ADDRESS):
Abacus Controls
P. O. Box 893
Somerville, NJ 08876

TELEPHONE: (201) 526-6010

PRINCIPAL INVESTIGATOR: George O'Sullivan

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5206

PROJECT ENGINEER: C. M. Coats

CURRENT CONTRACT PERIOD:
FROM: 1/24/80 **TO:** 9/31/80

PROBABLE PROJECT COMPLETION DATE: 12/31/80

AREA/TASK: Power Conditioning and Control /2.2

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 66400	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Design and build a 75 kW PV solar array simulator

DELIVERABLES:

Hardware

STATUS:

In design phase

Hardware expected 12/80

BEST DOCUMENT AVAILABLE

184

DATE PREPARED: 8/28/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Glass Headlamp Concentrator Development
CONTRACT NUMBER: 07-6922

CONTRACTOR (NAME AND ADDRESS):
Acurex Corporation
485 Clyde Avenue
Mountain View, California

TELEPHONE: (415) 964-3200
PRINCIPAL INVESTIGATOR: William Masters

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5634
PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:
FROM: 2/01/78 **TO:** 10/31/80

PROBABLE PROJECT COMPLETION DATE: 10/31/80

AREA/TASK: Concentrator Concept Development/ 5.1

CONTRACT FUNDING:

FY	$	SOURCE
79	227800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this project is to develop a photovoltaic concentrator module which essentially utilizes technology similarly employed in the manufacture of sealed beam auto and aircraft headlights. The project will determine the feasibility of designing and fabricating photovoltaic concentrator modules which are 8" in diameter, which consist of a transparent glass cover fused to a silvered glass reflector, with a concentrator silicon cell mounted at the focus of the parabolic dish reflector element.

DELIVERABLES:

A 36 unit array.

Final Report due.

STATUS:

The array has been fabricated and tested.

Delivery is scheduled for August 1980.

DATE PREPARED: 8/25/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Parabolic Trough Development

CONTRACT NUMBER: 13-9493

CONTRACTOR (NAME AND ADDRESS):

Acurex Corporation
485 Clyde Ave.
Mountain View, CA 94042

TELEPHONE: (415) 964-3200

PRINCIPAL INVESTIGATOR: D. Rafinejad

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5634

PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:

FROM: 11/09/79 TO: 12/31/80

PROBABLE PROJECT COMPLETION DATE: 12/31/80

AREA/TASK: Concentrator Manufacturing Development/5.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	218700	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. Develop an improved receiver design for Acurex's PV trough.
2. Investigate different ways of using silvered glass mirrors on their trough.
3. Investigate analytically the effects of a split-trough design.

DELIVERABLES:

A trough with glass reflectors, and several prototype receivers.

STATUS:

Samples of the reflector materials and receiver have been received and tested.

Prototype fabrication is underway.

DATE PREPARED: 8/26/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Off Farm Agricultural Applications

CONTRACT NUMBER: 62-6590

CONTRACTOR (NAME AND ADDRESS): Advanced Technology Inc. 7923 Jones Branch Drive McLean, VA 22102	**DIRECTING ORGANIZATION AND ADDRESS:** Sandia National Laboratories Albuquerque, New Mexico 87185
TELEPHONE: (704) 442-4000	**TELEPHONE:** (505) 844-7825
PRINCIPAL INVESTIGATOR: H. W. Warren	**PROJECT ENGINEER:** J. L. Jackson

CURRENT CONTRACT PERIOD:

FROM: 10/14/80 **TO:** 12/14/81

PROBABLE PROJECT COMPLETION DATE: 12/14/81

AREA/TASK: Applications Analysis/1.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	242000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. Develop data base of energy consumption patterns in Off-Farm Agricultural sector for use in subsequent tasks.
2. Identify those applications which can most effectively substitute PV for conventional power systems.
3. Develop conceptual PV designs for applications identified.
4. Estimate performance & life cycle costs for proposed conceptual designs
5. Recommend appropriate applications for near term experimental/demonstration projects

DELIVERABLES:

Technical Report

STATUS:

Contract underway. Kickoff meeting held November 11, 1980

DATE PREPARED: 11/12/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Systems and Applications Support
CONTRACT NUMBER: 13-5122

CONTRACTOR (NAME AND ADDRESS):
Aerospace Corporation
P. O. Box 92957
Los Angeles, CA 90009

TELEPHONE: (213) 648-7126
PRINCIPAL INVESTIGATOR: Barry Siegel

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2178
PROJECT ENGINEER: E. L. Burgess

CURRENT CONTRACT PERIOD:
FROM: 4/12/79 TO: 8/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Planning and evaluation /8.1

CONTRACT FUNDING:

FY	$	SOURCE
79	170000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The Aerospace Corporation shall review PRDA Phase I final reports, and prepare a report that summarizes the system concepts and major results. Aerospace will provide technical assistance to Sandia during Phase II of the contracts.

DELIVERABLES:

Final Report

STATUS:

Phase I has been completed.

DATE PREPARED: 8/25/80

188

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Residential Design Sensitivity Analysis
CONTRACT NUMBER: 62-6697

CONTRACTOR (NAME AND ADDRESS):
AIA Research Corporation
1735 New York Ave., NW
Washington, DC 20006

TELEPHONE: (202) 626-7544
PRINCIPAL INVESTIGATOR: George Royal

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2433
PROJECT ENGINEER: G. J. Jones

CURRENT CONTRACT PERIOD:
FROM: 7/28/80 **TO:** 3/28/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Conceptual Design and Optimization /1.2

CONTRACT FUNDING:

FY	$	SOURCE:
80	49700	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To analyze current designs, investigate the effects of "marketable" passive solar features, and determine the range of space conditioning loads expected.

Task I - Critique of the assumptions used in base design and analysis of the 1986 prototype residences.

Task II - Modification of prototype residences.

Task III - Simulation of the performance of these modified residences and evaluation of the results.

DELIVERABLES:

Monthly progress report

Quarterly oral review

STATUS:

Work just beginning. Data from GE and Westinghouse studies now being assembled.

DATE PREPARED: 8/27/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Solar Cell Development CONTRACT NUMBER: 49-2670	
CONTRACTOR (NAME AND ADDRESS): Applied Solar Energy Corp. P. O. Box 1212 City of Industry, CA 91749 TELEPHONE: (213) 968-6581 PRINCIPAL INVESTIGATOR: Ken Ling	DIRECTING ORGANIZATION AND ADDRESS: Sandia National Laboratories Albuquerque, New Mexico 87185 TELEPHONE: (505) 844-8979 PROJECT ENGINEER: H. T. Weaver
CURRENT CONTRACT PERIOD: FROM: 4/1/80 TO: 4/1/81	CONTRACT FUNDING: SOURCE: FY 80 $ 299300 DOE AN-15 FY ___ $ ___ FY ___ $ ___ FY ___ $ ___ FY ___ $ ___
PROBABLE PROJECT COMPLETION DATE:	
AREA/TASK: Silicon Cells /4.1	

SUMMARY:

CONTRACT OBJECTIVES:

Develop method for fabricating high efficiency solar cells.

DELIVERABLES:

25 cells

STATUS:

In progress.

DATE PREPARED: 9/22/80

BEST DOCUMENT AVAILABLE

190

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Cell Production Development
CONTRACT NUMBER: 13-0360

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corp.
P. O. Box 1212
City of Industry, CA 91749

TELEPHONE: (213) 968-6581
PRINCIPAL INVESTIGATOR: Ken Ling

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 2/14/79 **TO:** 12/31/79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:		SOURCE:
FY 79	$ 157700	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

The object of this contract is to develop manufacturing processes for lowering the silicon solar cell cost.

DELIVERABLES:

Technical Report

STATUS:

Completed 12/79

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Concentrator Cell Assembly Development
CONTRACT NUMBER: 13-2354

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corporation
P. O. Box 1212
City of Industry, CA 91749

TELEPHONE: (213) 968-6521
PRINCIPAL INVESTIGATOR: Ken Ling

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 2/08/79 TO: 1/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 148100	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Fabricate automatic cell assembler.

DELIVERABLES:

Technical Report

SAND80-7103

STATUS:

Complete

DATE PREPARED: 9/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cells
CONTRACT NUMBER: 28-1095

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corp.
P. O. Box 1212
City of Industry, CA 91749

TELEPHONE: (213) 968-6581
PRINCIPAL INVESTIGATOR: Ken Ling

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 5/1/80 **TO:** 9/1/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	25000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Fabricate solar cells for use in SNLA array.

DELIVERABLES:

1000 cells

STATUS:

Complete

DATE PREPARED: 9/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cells
CONTRACT NUMBER: 42-5979

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corp.
P. O. Box 1212
City of Industry, CA 91749

TELEPHONE: (213) 968-6581
PRINCIPAL INVESTIGATOR: Ken Ling

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 11-1-79 **TO:** 2-28-80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 28800	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Develop methods of fabricating high efficiency solar cells.

DELIVERABLES:

25 cells

STATUS:

In progress

DATE PREPARED: 9/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Cell Development
CONTRACT NUMBER: 46-2042A

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corporation
P. O. Box 1212
City of Industry, CA 91749

TELEPHONE: (213) 968-6581
PRINCIPAL INVESTIGATOR: Ken Ling

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 7-1-80 **TO:** 1-1-81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE
80	45600	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Fabricate and place silicon cells on assembly unit

DELIVERABLES:

4 Units

STATUS:

In progress

DATE PREPARED: 9/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Plastic Dish Module Development
CONTRACT NUMBER: 13-5162

CONTRACTOR (NAME AND ADDRESS):
Arizona Scientific Research
10121 Catalina Hwy.
Tucson, AZ 85715

TELEPHONE: (602) 749-3954
PRINCIPAL INVESTIGATOR: W. Meinel

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, NM 87185

TELEPHONE: (505) 844-5634
PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:
FROM: 6/13/79 **TO:** 11/30/80

PROBABLE PROJECT COMPLETION DATE: 2/28/81

AREA/TASK: Concentrator Manufacturing Development/5.2

CONTRACT FUNDING:

FY	$	SOURCE
79	162800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Under this contract, ASR will develop a design for a reflective dish PV concentrator which attempts to maximize module efficiency and minimize costs. The design will utilize a pedestal receiver with Si cells mounted around its perimeter. Several prototypes will be built.

DELIVERABLES:

Several prototypes will be delivered.

STATUS:

Design is complete. Prototype fabrication is underway.

BEST DOCUMENT AVAILABLE

DATE PREPARED; 8/26/80

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JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Concentrator Technology Studies
CONTRACT NUMBER: 49-1510

CONTRACTOR (NAME AND ADDRESS):
Arizona State University
Mechanical Engr. Dept.
Tempe, AZ 85281

TELEPHONE: (602) 965-3857
PRINCIPAL INVESTIGATOR: Dr. C. Backus

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604
PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:
FROM: 1/1/80 **TO:** 12/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	150000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Test and evaluation of concentrator cells, receivers, and complete modules. Also included is the development of standard test methods for the above.

DELIVERABLES:

Final Report

STATUS:

In progress

197

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/24/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Subsystem Model Study

CONTRACT NUMBER: 13-0313

CONTRACTOR (NAME AND ADDRESS):

Arizona State University
Tempe, Arizona 85281

TELEPHONE: (602) 965-3291

PRINCIPAL INVESTIGATOR: Donovan L. Evans

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2387

PROJECT ENGINEER: K. L. Biringer

CURRENT CONTRACT PERIOD:

FROM: 7/17/78 TO: 9/1/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Engineering Development/1.3

CONTRACT FUNDING:

		SOURCE:
FY 78	$ 58300	DOE AN-15
FY 79	$ 30000	
FY 80	$ 5000	
FY	$	
FY TOTAL	$ 93000	

SUMMARY:

CONTRACT OFJECTIVES:

The purposes of this solar photovoltaic study are to investigate simplifications in the modeling of photovoltaic subsystem components and to assess design sensitivity to system electrical load variations.

Task 1: Computer models of the PV array, battery, regulator and inverter are to be studied.

Objectives: To establish simplified computational techniques without loss of accuracy, and to compare these existing component models and results.

Task 2: Study the effects of variations in the assumed load profile on photovoltaic system designs.

Task 3: Develop and document a user guide to the simplified design techniques developed during the contract. Further analysis on the effects of short-term transients on the system performance is to be conducted.

STATUS:

Final Report received SAND80-7013.

User guide due 09/80

DATE PREPARED: 8/26/80

BEST DOCUMENT AVAILABLE

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Concentrator Studies

CONTRACT NUMBER: 13-5025

CONTRACTOR (NAME AND ADDRESS): Arizona State University Mechanical Engr. Dept. Tempe, AZ 85281 **TELEPHONE:** (602) 965-3857 **PRINCIPAL INVESTIGATOR:** C. Backus	**DIRECTING ORGANIZATION AND ADDRESS:** Sandia National Laboratories Albuquerque, New Mexico 87185 **TELEPHONE:** (505) 844-7604 **PROJECT ENGINEER:** B. D. Shafer

CURRENT CONTRACT PERIOD:

FROM: 2/1/79 **TO:** 2/1/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	122500	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Test and evaluation of concentrator cells, receivers, and complete modules. This work includes the development of standard test methods for the above.

DELIVERABLES:

Final report

STATUS:

Completed 1/80

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DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Photovoltaic Institutional Issues Study

CONTRACT NUMBER: 13-2320

CONTRACTOR (NAME AND ADDRESS):
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

TELEPHONE: (614) 424-6473

PRINCIPAL INVESTIGATOR: George Watkins

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2387

PROJECT ENGINEER: K. L. Biringer

CURRENT CONTRACT PERIOD:

FROM: 2/8/79 TO: 12/8/79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Applications Analysis/1.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	115000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The objectives of this work are to identify the institutional issues associated with the design, installation, and operation of on-site photovoltaic systems and to recommend approaches to dealing with significant institutional barriers to PV penetration.

The work has been divided into four task elements. These are:

1. Codes, ordinances, and standards
2. Financial and taxation
3. Insurance and liability
4. Environment and others

CONTRACT STATUS:

Completed 01/80

Final report received, SAND79-7054

DATE PREPARED: 8/26/80

TITLE: Solar Cell Encapsulation Development
CONTRACT NUMBER: 13-3567

CONTRACTOR (NAME AND ADDRESS):
Battelle
Columbus Laboratories
Columbus, OH

TELEPHONE:
PRINCIPAL INVESTIGATOR:

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-6372
PROJECT ENGINEER: R. A. Assink

CURRENT CONTRACT PERIOD:
FROM: 2/24/79 **TO:** 2/24/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE
79	99700	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this study is to develop and validate the performance of a prototype encapsulant system for the Sandia-type solar cell used in point-focusing photovoltaic arrays. The program consists of five integrated tasks: (1) Selection of candidate materials and measurement of unknown key properties, (2) Development of an experimental heat sink for the cell to accommodate detailed optical, thermal, and current-output measurements, (3) Development of processes to apply encapsulated cells before and after exposure to selected environmental overstresses (5) Analysis of the performance data to validate and upgrade the analytical models used and to recommend preferred encapsulant systems.

DELIVERABLES:

Technical Report

STATUS:

Completed

Final Report received 5/80.

DATE PREPARED: 9/23/80

BEST DOCUMENT AVAILABLE

TITLE: Intermediate Sector Retrofit Study

CONTRACT NUMBER: 62-1259

CONTRACTOR (NAME AND ADDRESS):
Battelle Columbus Laboratories
505 King Avenue
Columbus, OH 43201

TELEPHONE: (614) 424-7481
PRINCIPAL INVESTIGATOR: G. T. Noel

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7825
PROJECT ENGINEER: J. L. Jackson

CURRENT CONTRACT PERIOD:
FROM: 8/12/80 **TO:** 10/12/80

PROBABLE PROJECT COMPLETION DATE: 10/12/80

AREA/TASK: Applications Analysis /1.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 189578	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

1. Review existing literature and characterize existing intermediate structures in NE, SE & SW U.S.
2. Select representative intermediate sector structures and appropriate PV systems for retrofitting to these structures.
3. Propose detailed retrofitting schemes and estimate resultant costs. Estimate potential market.
4. Recommend development of special or unique hardware which might be needed for widespread intermediate PV retrofit.

DELIVERABLES:

Final report due two months after conclusion of technical effort.

STATUS:

Work in progress.

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Determine Cell Parameters
CONTRACT NUMBER: 62-0214

CONTRACTOR (NAME AND ADDRESS):
BDM Corporation
1801 Randolph Drive, SE
Albuquerque, NM 87106

TELEPHONE: (505) 848-5371
PRINCIPAL INVESTIGATOR: T. Lambarski

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2387
PROJECT ENGINEER: C. B. Rogers

CURRENT CONTRACT PERIOD:
FROM: 4/14/80 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 11/30/80

AREA/TASK: Conceptual Design and Optimization /1.2

CONTRACT FUNDING:

FY	$	SOURCE
80	59500	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. Develop software that will accomplish the necessary data reduction to obtain cell or module parameters from IV curves.
2. Install the software in the PVTAP code and also as a stand-alone program on the Sandia NOS computer system.

DELIVERABLES:

1. Final Report.
2. Software for stand-alone program.

STATUS:

1. The necessary modifications to the PVTAP code have been coded and are currently being checked out on the AFWL CDC-6600 computer.

DATE PREPARED: 9/24/80

BEST DOCUMENT AVAILABLE

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Determination of Detailed Residential Load Profile

CONTRACT NUMBER: 62-3977

CONTRACTOR (NAME AND ADDRESS):
BDM Corporation
1809 Randolph SE
Albuquerque, NM 87106

TELEPHONE: (505) 848-5000

PRINCIPAL INVESTIGATOR: G. C. Collaras

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, NM 87185

TELEPHONE: (505) 844-7825

PROJECT ENGINEER: J. L. Jackson

CURRENT CONTRACT PERIOD:

FROM: 10/14/80 **TO:** 12/14/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Applications Analysis/1.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	197000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. A comprehensive survey of utilities and related sources to determine availability of real-time instantaneous and time averaged load data for typical residences.
2. A direct measurement program in the three regions (NE, SE, & SW CONUS) to supplement data gaps.
3. Development of a statistical load model to predict the frequency and intensity of instantaneous spikes.
4. Verify model and the calculations of the annual load demand met by a PV system.

DELIVERABLES:

Technical Report

STATUS:

Contract underway. Kickoff meeting held 11/4/80

BEST DOCUMENT AVAILABLE

DATE PREPARED: 11/12/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design of Low-Cost Flat Plate Structures CONTRACT NUMBER: 05-6195	
CONTRACTOR (NAME AND ADDRESS): Bechtel National, Inc. P. O. Box 3965 San Francisco, CA 94119 TELEPHONE: (415) 768-8778 PRINCIPAL INVESTIGATOR: H. A. Franklin	DIRECTING ORGANIZATION AND ADDRESS: Sandia National Laboratories Albuquerque, New Mexico 87185 TELEPHONE: (505) 844-2154 PROJECT ENGINEER: H. N. Post
CURRENT CONTRACT PERIOD: FROM: 9/14/77 TO: 5/23/80	CONTRACT FUNDING: SOURCE: FY 77 $ 165000 DOE AN-15 FY 79 $ 181700 FY ___ $ ___ FY ___ $ ___ FY ___ $ ___
PROBABLE PROJECT COMPLETION DATE:	
AREA/TASK: Array Technology /2.1	

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this work is to develop detailed designs of structures for photovoltaic arrays which conform to mass production techniques, optimized material selections, and simplified installation methods, all leading to reduce system costs.

An additional objective is to develop a recommendation for usable, realistic, and practical wind load design criteria for photovoltaic array fields. This includes the planning, conduct and evaluation of a wind tunnel testing program for scale models of flat panel array fields.

DELIVERABLES:

Final Reports SAND79-7002 and SAND79-7057

STATUS:

Completed

DATE PREPARED: 9/24/80

BEST DOCUMENT AVAILABLE

205

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Subsystem Optimization and Design Tradeoff Study

CONTRACT NUMBER: 46-0042

CONTRACTOR (NAME AND ADDRESS):

Bechtel National, Inc.
P. O. Box 3965
San Francisco, CA 94119

TELEPHONE: (415) 768-5834

PRINCIPAL INVESTIGATOR: W. J. Stolte

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2433

PROJECT ENGINEER: G. J. Jones

CURRENT CONTRACT PERIOD:

FROM: 04/01/80 TO: 04/01/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Engineering Support /1.3

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 286600	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

The purpose of this contract is to address certain topics regarding engineering design options and subsystem specification specifically for large intermediate and central station applications.

Task I - Field design and wiring layout optimization for large ground mounted arrays.

Task II - Power conditioning type and selection for large application and subfield size selection based on PCU cost and array voltage requirement.

Task III - Support structure design and installation automation and analysis of roof mounted structures.

DELIVERABLES:

Final report

STATUS:

Work on all tasks is proceeding on schedule. Computer modeling of array field wiring has been accomplished and numerous tradeoffs analyzed. First Quarterly review was held in July.

DATE PREPARED: 8/27/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cell Development
CONTRACT NUMBER: 46-2122

CONTRACTOR (NAME AND ADDRESS):
Boeing
P. O. Box 3999 M/S 88-05
Seattle, WA 98124

TELEPHONE: (206) 773-2298
PRINCIPAL INVESTIGATOR: Betty Zimmerman

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, NM 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 2/1/80 **TO:** 3/30/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE
80	144100	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop methods for plating narrow metal lines on cells.

DELIVERABLES:

10 cells

STATUS:

In progress

DATE PREPARED: 9/17/80

BEST DOCUMENT AVAILABLE

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Operation of Data Reduction Center
CONTRACT NUMBER: 13-8019

CONTRACTOR (NAME AND ADDRESS):
Boeing Computer Service Co.
Box 3707
Seattle, Washington 98124

TELEPHONE: (206) 575-5155
PRINCIPAL INVESTIGATOR: Joseph T. Muldoon

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2807
PROJECT ENGINEER: H. D. Pruett

CURRENT CONTRACT PERIOD:
FROM: 1/31/80 **TO:** 1/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Data Reduction and Reporting /7.2

CONTRACT FUNDING:

FY	$	SOURCE:
80	708200	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To collect, archive and disseminate photovoltaic data and information

DELIVERABLES:

Monthly and quarterly reports

Several specific documents

STATUS:

On schedule

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/26/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Enclosed Air-Supported Concentrator Development
CONTRACT NUMBER: 13-5060

CONTRACTOR (NAME AND ADDRESS):
Boeing Engineering & Construction
P. O. Box 3707
Seattle, WA 98124

TELEPHONE: (206) 575-5731
PRINCIPAL INVESTIGATOR: John Laakso

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-4003
PROJECT ENGINEER: M. W. Edenburn

CURRENT CONTRACT PERIOD:
FROM: 4/25/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator Concept Development /5.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	203600	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Design and fabricate a 15 ft.-diameter air supported reflective film dish and test it to determine intensity distribution profiles on the receiver using a real sun test.

DELIVERABLES:

Final Report due

STATUS:

On schedule

DATE PREPARED: 8/28/80

TITLE: Economics of Photovoltaics
CONTRACT NUMBER: 49-5571

CONTRACTOR (NAME AND ADDRESS):
Brookhaven National Laboratories
Upton, NY 11973

TELEPHONE: (516) 345-2031
PRINCIPAL INVESTIGATOR: H. Davitian

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7825
PROJECT ENGINEER: J. L. Jackson

CURRENT CONTRACT PERIOD:
FROM: 4/1/80 **TO:** 4/1/81

PROBABLE PROJECT COMPLETION DATE: 4/30/81

AREA/TASK: Applications Analysis /1.1

CONTRACT FUNDING:		SOURCE:
FY 80	$ 140500	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Case studies to be conducted for three U.S. electric utilities to determine the economics of Photovoltaics for the utilities, the homeowner, and society as a whole. The three utilities will be chosen to form a representative cross-section of utilities nationwide.

DELIVERABLES:

Final report two months after completion of technical work.

STATUS:

Work in progress.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Sheet Molding Compound Trough Development
CONTRACT NUMBER: 13-8720

CONTRACTOR (NAME AND ADDRESS): The Budd Company Technical Center 375 Commerce Drive Fort Washington, Penn. 19034 TELEPHONE: (215) 643-2950 PRINCIPAL INVESTIGATOR: Paul A. Kirsch	DIRECTING ORGANIZATION AND ADDRESS: Sandia National Laboratories Albuquerque, New Mexico 87185 TELEPHONE: (505) 844-8643 PROJECT ENGINEER: R. L. Champion

CURRENT CONTRACT PERIOD:
FROM: 10/1/79 TO: 10/30/80
PROBABLE PROJECT COMPLETION DATE:
AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	105800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Investigate molding of glass mirrors as integral part of SMC molded panels. Design and fabricate tooling suitable for production of 150 parts. Mold two initial units for Sandia evaluation and approval. When approved, fabricate 30 units incorporating no glass, sagged glass and chemically strengthened glass.

DELIVERABLES:

32 SMC/glass panels

STATUS:

Ongoing. Mold development units in mid-September. Had problems molding parts in July and August at Ft. Washington.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/17/80

211

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Stamped Sheet Metal Trough Development
CONTRACT NUMBER: 13-8721

CONTRACTOR (NAME AND ADDRESS):
The Budd Company
Technical Center
375 Commerce Drive
Fort Washington, Penn. 19034
TELEPHONE: (215) 643-2950
PRINCIPAL INVESTIGATOR: A. W. Biester

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-8643
PROJECT ENGINEER: R. L. Champion

CURRENT CONTRACT PERIOD:
FROM: 9/01/79 **TO:** 12/01/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 187700	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Investigate fabrication of stamped sheet metal parabolic trough reflector panels. Determine tooling requirements and accuracy obtained with sheet metal panels produced with quasi-production tooling and high volume production techniques.

DELIVERABLES:

18 sheet metal panels (1x2m) of three configurations

STATUS:

Ongoing. Initial 2 units completed and being shipped to SLA for measurement on LRT and evaluation. Approval to go on remaining 16 pending.

DATE PREPARED: 9/17/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Solar Cell Research
CONTRACT NUMBER: 13-6199

CONTRACTOR (NAME AND ADDRESS):
California Inst. of Technology
1201 E. California Blvd.
Pasadena, CA 91125

TELEPHONE: (213) 795-6811 Ex.1803
PRINCIPAL INVESTIGATOR: Marc A. Nicolet

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 7/22/79 **TO:** 7/30/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE
79	245600	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop diffusion barriers for metal systems used in silicon solar cells.

DELIVERABLES:

Technical Report

STATUS:

In progress under an extension.

213

DATE PREPARED: 9/17/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Passive Cooling Studies
CONTRACT NUMBER: 62-1271

CONTRACTOR (NAME AND ADDRESS):
Energy Engineering Inc.
1704 Stanford NE
Albuquerque, NM 87106

TELEPHONE: (505) 277-6313
PRINCIPAL INVESTIGATOR: Tom Feldman

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-4003
PROJECT ENGINEER: M. W. Edenburn

CURRENT CONTRACT PERIOD:
FROM: 4/1/80 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator Concept Development /5.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	25100	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. Fabricating and testing a heat exchanger for a linear PV array.

DELIVERABLES:

Final Report due

STATUS:

On schedule

Interim report SAND80-7011

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/28/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Battery Handbook for Photovoltaic System Planners

CONTRACT NUMBER: 13-2202

CONTRACTOR (NAME AND ADDRESS):

ESB Inc.
Wisco Division
19 W. College Ave.
Yardley, PA 19067

TELEPHONE: (215) 493-7123

PRINCIPAL INVESTIGATOR: Frank Malaspina

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-6432

PROJECT ENGINEER: D. M. Bush

CURRENT CONTRACT PERIOD:

FROM: 11/01/78 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Energy Storage /2.3

CONTRACT FUNDING:

FY	$	SOURCE:
79	117900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Compile a handbook for photovoltaic system planners to include battery sizes and weights, cell voltages, charge and float voltages, watt-hours per pound and per cubic inch, typical lifetimes both in years and in number of charge/discharge cycles, deep discharge capabilities, and initial costs per watt-hours and per ampere-hours. Data will be taken from the literature and laboratory tests for nickel-cadmium and lead-acid batteries. In addition, cost performance tradeoffs for battery charging regulators in the 1 kW range will be investigated.

DELIVERABLES:

Handbook

STATUS:

Work completed.

Final in preparation.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/25/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Linear Fresnel Lens Development
CONTRACT NUMBER: 13-2359

CONTRACTOR (NAME AND ADDRESS):
E-Systems, Inc.
Energy Technology Center
P. O. Box 22618
Dallas, TX 75266
TELEPHONE: (214) 272-0515
PRINCIPAL INVESTIGATOR: M. O'Neill

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-2130
PROJECT ENGINEER: C. B. Stillwell

CURRENT CONTRACT PERIOD:
FROM: 1/3/79 **TO:** 9/30/80

CONTRACT FUNDING:

FY 79	**$** 213900	**SOURCE:** DOE AN-15
FY	**$**	
FY	**$**	
FY	**$**	
FY	**$**	

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator
Concept Development /5.1

SUMMARY:

CONTRACT OBJECTIVES:

To develop a low-cost linear Fresnel lens for photovoltaic concentrators using the extrusion/embossed process.

DELIVERABLES:

1. 100 square feet of linear Fresnel lens.
2. Monthly progress reports.
3. Final report.

STATUS:

First of 2 extrusion runs specified in change order #2 to be made the week of August 18.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Linear Fresnel Lens Array Development
CONTRACT NUMBER: 46-5791

CONTRACTOR (NAME AND ADDRESS):
E-Systems
Energy Technology Center
P. O. Box 6118
Dallas, TX 75222
TELEPHONE: (214) 272-0515 X-3830
PRINCIPAL INVESTIGATOR: M. O'Neill

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-7604
PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:
FROM: 1/31/80 **TO:** 1/31/81

PROBABLE PROJECT COMPLETION DATE: 1/31/80

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE
80	349200	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop a second generation linear focus photovoltaic concentrator array. The unit is aimed at meeting $2.80/Watt DOE goal. It is expected to have an efficiency of 13-15% and low cost tracking structure.

DELIVERABLES:

A 3.5 kW photovoltaic concentrator array plus two prototype modules for environmental evaluation.

STATUS:

Design has been completed, and prototype modules are being fabricated.

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Development and Study of Sagged Glass Sheets
CONTRACT NUMBER: 13-2348

CONTRACTOR (NAME AND ADDRESS):
Ford Aerospace & Communications Corp.
3939 Fabian Way
Palo Alto, CA 94303
TELEPHONE: (415) 494-7400
PRINCIPAL INVESTIGATOR: Earl Lewis

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-3773
PROJECT ENGINEER: S. B. Martin

CURRENT CONTRACT PERIOD:
FROM: 7/2/79 **TO:** 9/1/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator Manufacturing Development /5.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	101200	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To thermally form glass to parabolic contours using automotive windshield production type processes and to provide cost estimates of same.

DELIVERABLES:

Hardware received

Final report

STATUS:

Total contract value = $133700

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Low-cost, Two-axis Tracking Structure
CONTRACT NUMBER: 13-9495

CONTRACTOR (NAME AND ADDRESS):
Ford Aerospace & Communications Corp.
3939 Fabian Way
Palo Alto, CA 94303
TELEPHONE: (415) 494-7400 X4594
PRINCIPAL INVESTIGATOR: H. Sund

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-7604
PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:
FROM: 12/4/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 10/31/80

AREA/TASK: Array Design and Evaluation /6.2

CONTRACT FUNDING:

FY	$	SOURCE
80	230800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Design and fabricate a low-cost two-axis tracking structure for use with photovoltaic concentrator arrays. This turntable design is meant to be used for central station or intermediate load center applications.

DELIVERABLES:

An 85-ft diameter, two-axis tracking structure

STATUS:

The structure has been designed and is being fabricated.

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Direct Current Loads Applications Study
CONTRACT NUMBER: 13-0278

CONTRACTOR (NAME AND ADDRESS):
General Electric Systems
Operations
Valley Forge, Pennsylvania

TELEPHONE: (215) 962-5842
PRINCIPAL INVESTIGATOR: E. M. Mehalick

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-3043
PROJECT ENGINEER: D. R. Smith

CURRENT CONTRACT PERIOD:
FROM: 12/1/78 TO: 9/1/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Applications Analysis /1.

CONTRACT FUNDING:

FY	$	SOURCE:
79	143900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The objectives of this study are:

1. to identify significant loads which are either presently being met or could be met with DC electricity and
2. to classify these loads according to their potential for conversion to photovoltaic power.
3. Conceptual designs are to be provided for complete DC photovoltaic systems for the three most promising loads.

DELIVERABLES:

Technical Report

STATUS:

Final Report in review - SAND80-7149.

220

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design of Residential Load Centers

CONTRACT NUMBER: 13-2283

CONTRACTOR (NAME AND ADDRESS):
General Electric
Space Systems Division
Valley Forge, PA

TELEPHONE: (215) 962-5842

PRINCIPAL INVESTIGATOR: Ed Mehalick

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2387

PROJECT ENGINEER: C. B. Rogers

CURRENT CONTRACT PERIOD:

FROM: 12/20/78 **TO:** 11/15/80

PROBABLE PROJECT COMPLETION DATE: 11/15/80

AREA/TASK: Conceptual Design and Optimization /1.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	229700	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The contractor shall

1. Classify residential load center types.
2. Define system configurations applicable to residential load centers.
3. Perform detailed tradeoff studies of four to eight systems in each region.
4. Prepare conceptual designs of the more promising systems.

DELIVERABLES:

1. Final Report following completion of contract work.

STATUS:

Analysis of side-by-side thermal/PV systems remains to be done. Other work including portions of the final report have been completed.

DATE PREPARED: 9/24/80

BEST DOCUMENT AVAILABLE

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Epoxy Parabolic Trough Development

CONTRACT NUMBER: 13-2360

CONTRACTOR (NAME AND ADDRESS):
General Electric Co.
Advanced Energy Programs
P. O. Box 8661
Philadelphia, PA 19101

TELEPHONE: (215) 962-5949

PRINCIPAL INVESTIGATOR: Ron Hodge

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2154

PROJECT ENGINEER: H. N. Post

CURRENT CONTRACT PERIOD:

FROM: 1/31/79 **TO:** 7/15/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator Concept Development /5.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	266900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this work is to develop a design for a plastic material-process combination which will result in reduced production costs for line focus trough concentrator modules for photovoltaic arrays.

DELIVERABLES:

Interim Report SAND80-7003

Prototype plastic troughs

STATUS:

Final Report in preparation.

DATE PREPARED: 8/27/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Concentrator Array Manufacturing Cost Analysis

CONTRACT NUMBER: 13-2377

CONTRACTOR (NAME AND ADDRESS):
General Electric
P. O. Box 8661
Philadelphia, PA 19101

TELEPHONE: (215) 962-5949

PRINCIPAL INVESTIGATOR: R. C. Hodge

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5634

PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:

FROM: 1/25/79 TO: 2/28/80

PROBABLE PROJECT COMPLETION DATE: Done

AREA/TASK: Concentrator Manufacturing Development /5.2

CONTRACT FUNDING:		SOURCE:
FY 79	$ 184300	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

This contract is for a detailed manufacturing process and cost analysis for several leading PV concentrator concepts.

DELIVERABLES:

The Final Report has been delivered. The Sandia Laboratories report number is SAND79-7055.

STATUS:

Contract complete

DATE PREPARED: 8/26/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Concentrator Cell Mount Assembly

CONTRACT NUMBER: 13-5075

CONTRACTOR (NAME AND ADDRESS):
General Electric Co.
Space Systems Operations
P. O. Box 8661
Philadelphia, PA 19101

TELEPHONE: (215) 962-5839

PRINCIPAL INVESTIGATOR: Neal Shepard

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604

PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:

FROM: 8/31/79 **TO:** 8/31/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	184500	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop and fabricate cell assemblies for use in point focus photovoltaic concentrator arrays. The cell assemblies are made in a manner similar to that used for power diode technology, thus lend themselves to high volume, low cost fabrication.

DELIVERABLES:

1,000 cell assemblies

STATUS:

500 of the cell assemblies have been fabricated and delivered. Testing of the units indicates that they perform as predicted.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: High Concentration Module Development **CONTRACT NUMBER:** 13-9434	
CONTRACTOR (NAME AND ADDRESS): General Electric Advanced Energy Department P. O. Box 8661 Philadelphia, PA 19101 **TELEPHONE:** (215) 962-5949 **PRINCIPAL INVESTIGATOR:** Ron Hodge	**DIRECTING ORGANIZATION AND ADDRESS:** Sandia National Laboratories Albuquerque, New Mexico 87185 **TELEPHONE:** (505) 844-5634 **PROJECT ENGINEER:** E. C. Boes
CURRENT CONTRACT PERIOD: **FROM:** 1/14/80 **TO:** 2/28/81	**CONTRACT FUNDING:** / **SOURCE:** **FY** 80 **$** 315000 DOE AN-15 **FY** **$** **FY** **$** **FY** **$** **FY** **$**
PROBABLE PROJECT COMPLETION DATE:	
AREA/TASK: Concentrator Concept Development /5.1	

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this program is to design and demonstrate via prototype hardware a high efficiency (>15%) high concentration ratio (400-2000X) photovoltaic module.

DELIVERABLES:

A prototype module

STATUS:

Design is complete. Lens cutting is underway.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/23/80

225

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Concentrator Cell Assembly Development

CONTRACT NUMBER: 13-8893

CONTRACTOR (NAME AND ADDRESS):
General Electric
Advanced Energy Program
P. O. Box 8661
Philadelphia, PA 19101

TELEPHONE: (518) 385-3473

PRINCIPAL INVESTIGATOR: Neal Shepard

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979

PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 9/25/79 **TO:** 7/30/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE
79	343200	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop vertical junction solar cell

DELIVERABLES:

25 cells

STATUS:

Contract being extended -- work in progress

DATE PREPARED: 9/17/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Residential Preferred Design Development
CONTRACT NUMBER: 13-8779

CONTRACTOR (NAME AND ADDRESS):
General Electric Co.
Space Systems Division
Valley Forge, Pennsylvania

TELEPHONE: (215) 962-5842
PRINCIPAL INVESTIGATOR: E. M. Mehalick

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2433
PROJECT ENGINEER: G. J. Jones

CURRENT CONTRACT PERIOD:
FROM: 8/2/79 **TO:** 1/31/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Conceptual Design and Optimization /1.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	366900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The contractor is to review all residential photovoltaic systems work done to date. Based on these data and supplementary analysis nine designs spread over three regions which represent the most viable systems and cover the technology options. Five of these will be chosen to take through a preliminary design phase indicating all necessary electrical and mechanical hardware and their specifications. This work is in direct support of the residential test and application program forming the input to the regional appropriate system designs. In addition these results will be used for detailed system costing studies and other DOE activities.

STATUS:

The Southwest All-Electric Residence Design (SAND79-7056) was released in February. The second design report is being reviewed, while the third report is in preparation. These cover a PV/thermal side-by-side system for the northeast and battery storage in the southwest respectively. Work on a passive residence for the northeast is underway as design four.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/27/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Energy Scenario Effects Study
CONTRACT NUMBER: 13-9482

CONTRACTOR (NAME AND ADDRESS):
General Electric
1 River Road
Schenectady, N.Y. 12345

TELEPHONE: (518) 385-4097
PRINCIPAL INVESTIGATOR: Gary Bonk

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2433
PROJECT ENGINEER: G. J. Jones

CURRENT CONTRACT PERIOD:
FROM: 04/07/80 **TO:** 04/07/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Applications Analysis /1.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	401600	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The work should result in a broad coverage of possible utility energy rate scenarios, an identification of significant parameters in these scenarios and an explanation of the impact of variations in these parameters on PV system implementation.

Task I - Identify and describe a group of generic photovoltaic system configurations representing current possibilities.

Task II - Identify and describe a range of electric utility energy source scenarios using variations in assumptions on causal effects, economic and operational specifics and all other reasonable eventualities.

Task III - Determine the influences of various energy scenarios on decisions regarding the design and operation of candidate photovoltaic systems. Primary effort should be spent in this task.

DELIVERABLES:

Monthly progress report letters
Quarterly oral reviews
Final report

CONTRACT STATUS:

The first quarterly review in July resulted in selection of the energy scenarios to be evaluated. Participation of DOE/EES, ORNL, SERI in this review assured the maximum influence of their work.

DATE PREPARED: 8/27/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cell Development
CONTRACT NUMBER: 42-5807

CONTRACTOR (NAME AND ADDRESS): General Electric P. O. Box 43 Schenectady, NY 12345	DIRECTING ORGANIZATION AND ADDRESS: Sandia National Laboratories Albuquerque, New Mexico 87185
TELEPHONE: (518) 385-3473	TELEPHONE: (505) 844-8979
PRINCIPAL INVESTIGATOR: Bob Hall	PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 12/12/79 TO: 6/12/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:		SOURCE:
FY 80	$ 97600	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Develop techniques for fabricating linear receiver -- combined photovoltaic and thermal.

DELIVERABLES:

Two receivers

STATUS:

Complete -- Final report in print shop.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/17/80

229

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Array Manufacturing Cost Analysis for $\$2.80/W_p$

CONTRACT NUMBER: 62-6547

CONTRACTOR (NAME AND ADDRESS):

General Electric AED
P. O. Box 8661
Philadelphia, PA

TELEPHONE: (215) 962-5949

PRINCIPAL INVESTIGATOR: R. C. Hodge

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5634

PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:

FROM: 7/18/80 **TO:** 11/30/80

PROBABLE PROJECT COMPLETION DATE: 12/31/80

AREA/TASK: Concentrator Manufacturing Development /5.2

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 180000	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

1. Develop preferred manufacturing processes for $\$2.80/W_p$ PV concentrator array design.
2. Calculate manufacturing and installation prices for these arrays.

DELIVERABLES:

Final Report

STATUS:

Contract is just beginning. Design information is being compiled on the 3 arrays.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/26/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Laminated Glass-Acrylic Fresnel Lens Development

CONTRACT NUMBER: 46-0063

CONTRACTOR (NAME AND ADDRESS):
General Electric
Space Division
P. O. Box 8661
Philadelphia, PA 19101

TELEPHONE: (215) 962-5950

PRINCIPAL INVESTIGATOR: R. B. Hobbs, Jr.

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2130

PROJECT ENGINEER: C. B. Stillwell

CURRENT CONTRACT PERIOD:

FROM: 10/18/79 **TO:** 7/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	171800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To develop and fabricate laminated point focus Fresnel lenses using injection molded lenses bonded to glass

DELIVERABLES:

1. 10 ea laminated lenses
2. Monthly reports
3. Final report

STATUS:

10 ea laminated lenses received

DATE PREPARED: 8/26/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Prototype of 10 kW Passive Cooled Array

CONTRACT NUMBER: 07-7293

CONTRACTOR (NAME AND ADDRESS):
Honeywell, Inc.
2600 Ridgeway Parkway
Minneapolis, MN 55413

TELEPHONE: (612) 378-5496

PRINCIPAL INVESTIGATOR: Ray Stiles

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604

PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:

FROM: 9/8/78 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
78	443000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Design of a 10 kilowatt actively cooled photovoltaic concentrator array. The proposed design is a parabolic trough design that has 2-axis tracking via a center mount pedestal which provides Az-El tracking. Sagged glass, second surface silvered Corning 0317 glass constitutes the baseline reflective surface. The unit is required to produce 50 kW of thermal energy in addition to the 10 kW of electrical energy. The thermal output is with the outlet coolant temperature at 150°F.

DELIVERABLES:

A basic photovoltaic module, including concentrator optics and photovoltaic receiver. In addition, numerous subcomponents for environmental testing.

STATUS:

Completed through all deliverables and a draft of final report.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/24/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Parabolic Trough Development

CONTRACT NUMBER: 13-9458

CONTRACTOR (NAME AND ADDRESS): Inter-Technology Corporation 100 Main Street Warrenton, VA 22186 **TELEPHONE:** (703) 347-7900 **PRINCIPAL INVESTIGATOR:** H. Liers	**DIRECTING ORGANIZATION AND ADDRESS:** Sandia National Laboratories Albuquerque, New Mexico 87185 **TELEPHONE:** (505) 844-7604 **PROJECT ENGINEER:** B. D. Shafer
CURRENT CONTRACT PERIOD: **FROM:** 9/15/79 **TO:** 6/30/80	**CONTRACT FUNDING:** **SOURCE:** **FY** 79 **$** 37000 DOE AN-15 **FY** \_\_\_ **$** ___ **FY** ___ **$** \_\_\_ **FY** \_\_\_ **$** ___ **FY** ___ **$** ___
PROBABLE PROJECT COMPLETION DATE: 6/30/80	
AREA/TASK: Array Evaluation /6.2	

SUMMARY:

CONTRACT OBJECTIVES:

Fabricate a parabolic trough PV concentrator module as per the design developed under Phase I of PRDA-35.

DELIVERABLES:

A 250 watt PV concentrator module.

STATUS:

Completed

DATE PREPARED: 9/23/80

BEST DOCUMENT AVAILABLE

233

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Study of the Energy Performance of a Hybrid-Electric Automobile with a Photovoltaic Residence

CONTRACT NUMBER: 49-1533

CONTRACTOR (NAME AND ADDRESS):
JSR ASSOCIATES
2280 Hanover St.
Palo Alto, CA 94306

TELEPHONE: (415) 329-9289
PRINCIPAL INVESTIGATOR: John S. Reuyl

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2433
PROJECT ENGINEER: G. J. Jones

CURRENT CONTRACT PERIOD:
FROM: 3/17/80 **TO:** 12/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Conceptual Design and Optimization /1.2

CONTRACT FUNDING:

FY	$	SOURCE
80	43900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. Design a hybrid-electric automobile that can interface with a photovoltaic residence.
2. Provide candidate residential designs from other studies, review these designs and select one for study.
3. Conduct a preliminary study of the energy performance of the automobile and the residence involving both stand-alone residential applications as well as residences with electric grid hookups.

DELIVERABLES:

Monthly letter report and cost status

2 reviews

Final report

STATUS:

Initial analysis complete. Preliminary draft report being prepared.

DATE PREPARED: 8/27/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: 10 kW Fresnel Lens Array Fabrication
CONTRACT NUMBER: 07-9265

CONTRACTOR (NAME AND ADDRESS):
Martin Marrietta Corp.
Denver Div.
P. O. Box 179
Denver, CO 80201
TELEPHONE: (303) 329-2975
PRINCIPAL INVESTIGATOR: Dick Donovan

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-7604
PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:
FROM: 6/15/78 **TO:** 10/15/79

PROBABLE PROJECT COMPLETION DATE: Completed

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
78	499000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Fabricate point focus concentrator arrays that produce 2.2 kW of power. The units are to be pedestal moun for two axis tracking, and are designed for passive cooling.

DELIVERABLES:

Two 2.2 kW point focus photovoltaic concentrator arrays.

STATUS:

Completed 12/79; the arrays have functioned well for 9 months. This basic design was selected for the 450 kW SOLERAS project.

DATE PREPARED: 9/24/80

BEST DOCUMENT AVAILABLE

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Active Cooled Receiver Design for Fresnel Module
CONTRACT NUMBER: 13-8778

CONTRACTOR (NAME AND ADDRESS):
Martin Marietta
P. O. Box 179
Denver, CO 80201

TELEPHONE: (303) 789-1533
PRINCIPAL INVESTIGATOR: Sid Broadbent

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604
PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:
FROM: 8/9/79 TO: 8/31/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: Array Evaluation /6.2

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 217500	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Modify the Martin Marietta 10 kW passively cooled 2.5 kW photovoltaic concentrator for active cooling. This is to be done in a manner which will produce a minimum array cost, yet provide significant amount of useful thermal energy.

DELIVERABLES:

A 2.5 kW photovoltaic concentrator array.

STATUS:

The array is presently being fabricated.

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design Modifications on Fresnel Lens Array

CONTRACT NUMBER: 42-7260

CONTRACTOR (NAME AND ADDRESS):
Martin Marietta
P. O. Box 179
Denver, CO 80201

TELEPHONE: (303) 789-1533

PRINCIPAL INVESTIGATOR: Sid Broadbent

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604

PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:

FROM: 8/7/79 **TO:** 9/30/79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	52900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Modify the Martin Marietta 2.2 kW arrays to improve module seating to water.

DELIVERABLES:

Reworked modules

STATUS:

Completed 9/30/79

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Second Generation Point Focus Fresnel Lens Module
CONTRACT NUMBER: 46-3018

CONTRACTOR (NAME AND ADDRESS):
Martin Marietta
Box 179
Denver, CO 80201

TELEPHONE: (303) 789-1533
PRINCIPAL INVESTIGATOR: Sid Broadbent

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604
PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:
FROM: 1/31/80 TO: 1/31/81

PROBABLE PROJECT COMPLETION DATE: 1/31/81

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	353300	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The first generation point focus concentrator array fabricated by Martin Marietta has been one of best performing units fabricated to date. The present contract calls for Martin Marietta to keep the same overall array concept, while optimizing the components of the array. The goal was to have an array which could clearly meet the $2.80/$W_p$ goal.

DELIVERABLES:

Advanced PV modules, 3 each

STATUS:

In the design phase

DATE PREPARED: 9/18/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Weatherability of Sheet Moulding

CONTRACT NUMBER: 42-9503

CONTRACTOR (NAME AND ADDRESS):
Mass. Inst. of Techology
Dept. of Mat. Science & Engr.
77 Mass. Ave.
Cambridge, MA 02139

TELEPHONE: (617) 253-3309

PRINCIPAL INVESTIGATOR: Dave K. Roylance

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2436

PROJECT ENGINEER: R. E. Allred

CURRENT CONTRACT PERIOD:

FROM: 9-1-79 **TO:** 6-30-80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator Manufacturing Development/5.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	21000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Evaluate the outdoor weathering of Sheet Moulding Compound solar reflector structure

DELIVERABLES:

Final report

STATUS:

Completed 06/80

DATE PREPARED: 8/20/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Glass Reinforced Concrete Concentrator Array

CONTRACT NUMBER: 13-0309

CONTRACTOR (NAME AND ADDRESS):
M. B. Associates
Bollinger Canyon Road
San Ramon, CA 94503

TELEPHONE: (415) 837-7201

PRINCIPAL INVESTIGATOR: John Taylor

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2154

PROJECT ENGINEER: H. N. Post

CURRENT CONTRACT PERIOD:
FROM: 12/8/78 **TO:** 10/26/79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator Concept Development /5.1

CONTRACT FUNDING:

FY	$	SOURCE:
78	255900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To design, develop, and fabricate a prototype model of a novel, low-cost, two-axis tracking structure for use with high concentration ratio optics.

DELIVERABLES:

Prototype array installed at contractor's plant in San Ramon, CA. Final Report SAND79-7053.

STATUS:

Completed.

DATE PREPARED: 9/24/80

240

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Legal and Institutional Issues of Photovoltaics

CONTRACT NUMBER: 62-3996

CONTRACTOR (NAME AND ADDRESS):
Mel Eisenstadt & Associates
7800 Phoenix NE
Albuquerque, NM 87110

TELEPHONE: 505-296-2956
PRINCIPAL INVESTIGATOR: M. Eisenstadt

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, NM 87185

TELEPHONE: 505-844-7825
PROJECT ENGINEER: J. L. Jackson

CURRENT CONTRACT PERIOD:
FROM: 05/07/80 **TO:** 05/06/81

PROBABLE PROJECT COMPLETION DATE: 05/06/81

AREA/TASK: Applications Analysis /1.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	20,000	DOE AN-15

SUMMARY:

OBJECTIVES:

Provide legal evaluation as required on zoning, building ordinances, warranties, and government regulations impacting photovoltaics.

DELIVERABLES:

Technical Report

SAND80-7080

BEST DOCUMENT AVAILABLE

241

DATE PREPARED: 10/14/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cell Development
CONTRACT NUMBER: 13-0361

CONTRACTOR (NAME AND ADDRESS):

Microwave Associates
Burlington, Mass. 01803

TELEPHONE: (617) 272-3000
PRINCIPAL INVESTIGATOR: Bob Frank

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 12/05/78 **TO:** 12/31/79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	127600	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop silicon cell to operate in sunlight concentration above 500 suns.

DELIVERABLES:

Technical Report

125 cells

STATUS:

In progress under extension of original contract.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/17/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Concentrator Cell Assembly Development
CONTRACT NUMBER: 46-2034

CONTRACTOR (NAME AND ADDRESS):
Microwave Associates
Burlington, MA 01803

TELEPHONE: (617) 272-3000
PRINCIPAL INVESTIGATOR: Bob Frank

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 10/31/79 **TO:** 10/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 199200	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Develop assembly for cells operated at very high sunlight concentration.

DELIVERABLES:

10 units of cells plus assemblies

STATUS:

In progress

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/17/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Analysis of Cell Failure Due to Lightning
CONTRACT NUMBER: 62-2671

CONTRACTOR (NAME AND ADDRESS):
Mission Research Corp.
1400 San Mateo Blvd., SE
Albuquerque, NM 87108

TELEPHONE: (505) 265-8306
PRINCIPAL INVESTIGATOR: Ron Peace

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2387
PROJECT ENGINEER: C. B. Rogers

CURRENT CONTRACT PERIOD:
FROM: 10/1/80 **TO:** 6/30/81

PROBABLE PROJECT COMPLETION DATE: 6/30/81

AREA/TASK: Array Technology /2.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 85000	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

1. Determine damage thresholds to solar cells from pulsed sources. Pulse length shall be in the range of 0.1 to 100 microseconds.

DELIVERABLES:

1. Final Report.

STATUS:

1. Contract not yet placed.

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: On-Site Data Acquisition System Services
CONTRACT NUMBER: 49-4911

CONTRACTOR (NAME AND ADDRESS):
Mississippi Co. Comm. College
South Highway 61
Blytheville, Arkansas 72315

TELEPHONE: (501) 762-1020
PRINCIPAL INVESTIGATOR: Dr. Harry Smith

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8867
PROJECT ENGINEER: T. L. Evans

CURRENT CONTRACT PERIOD:
FROM: 8/1/80 **TO:** 9/30/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: On-Site Data Hardware/7.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 37700	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

1. Provide site application software for On-Site Data Acquisition System (ODAS).
2. Provide for installation, wiring, and checkout of ODAS and meteorological station.
3. Provide maintenance for weather station instruments for two years.
4. Allow data from photovoltaic project to be collected by Photovoltaic Data Reduction Center.

STATUS:

Contract placed with Mississippi County Community College (MCCC) on July 17, 1980. All hardware shipped to facility except for weather station which will be shipped week of 8/18/80. Contractor is delaying start of project until negotiations with SLA purchasing department are completed regarding selection of new subcontractor for software and installation phase.

DATE PREPARED: 8/26/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cell Production
CONTRACT NUMBER: 13-2355

CONTRACTOR (NAME AND ADDRESS):
Motorola, Inc.
Solar Operations
5005 East McDowell Rd.
Phoenix, AZ
TELEPHONE: (602) 244-6414
PRINCIPAL INVESTIGATOR: Larry Grenom

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-6137
PROJECT ENGINEER: R. D. Nasby

CURRENT CONTRACT PERIOD:
FROM: 12/11/78 **TO:** 12/31/79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells/4.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	181800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The purpose of the program is to evaluate and develop specific, state-of-the-art, process steps that exhibit major near-term improvements in cost, performance, and reliability of Si concentrator cells. Some of the primary areas are the use of thin substrates, further development of fine textured surfaces, ion implantation, improvement of metallization processes, and the development of 1 mil metal fingers on textured surfaces.

DELIVERABLES:

Technical Report
SAND80-7018

STATUS:

Completed 12/79

DATE PREPARED: 8/18/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cell Production Development

CONTRACT NUMBER: 13-6121

CONTRACTOR (NAME AND ADDRESS):

Motorola, Inc.
Semiconductor Group

TELEPHONE: (602) 244-6414

PRINCIPAL INVESTIGATOR: Larry Grenom

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-6137

PROJECT ENGINEER: R. D. Nasby

CURRENT CONTRACT PERIOD:

FROM: 5/1/79 TO: 5/1/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	100000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The object of this contract is to improve the efficiency of silicon solar cells using advanced processing methods.

DELIVERABLES:

Technical Report

Prototype cells

STATUS:

Complete 05/80

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/18/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cell Production

CONTRACT NUMBER: 28-1065

CONTRACTOR (NAME AND ADDRESS):

Motorola Semiconductor Division
5005 East McDowell Road
Phoenix, AZ

TELEPHONE: (602) 244-6414

PRINCIPAL INVESTIGATOR: Larry Grenom

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-6137

PROJECT ENGINEER: R. D. Nasby

CURRENT CONTRACT PERIOD:

FROM: 5/1/80 **TO:** 5/1/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells/4.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	197800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this contract is to improve the efficiency of silicon solar cells using advanced processing methods and to look at totally plated metallization systems.

This is an extension of contract #13-6121.

DELIVERABLES:

Technical Report
Prototype cells

STATUS:

Some problems in metallization process.

DATE PREPARED: 8/18/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Concentrator Cells
CONTRACT NUMBER: 42-5778

CONTRACTOR (NAME AND ADDRESS):
Motorola
P. O. Box 2953
Phoenix, Arizona

TELEPHONE: (602) 244-6414
PRINCIPAL INVESTIGATOR: Larry Grennon

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 11/01/79 **TO:** 2/28/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	18400	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Procure cells for array testing at SNLA.

DELIVERABLES:

750 cells (~1 in^2)

STATUS:

Complete

DATE PREPARED: 9/22/80

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JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: On-Site Data Acquisition System Services

CONTRACT NUMBER: 49-4912

CONTRACTOR (NAME AND ADDRESS):
NW Mississippi Junior College
Highway 51 North
Senatobia, Mississippi 38668

TELEPHONE: (601) 562-5262

PRINCIPAL INVESTIGATOR: Dr. June Gardner

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8867

PROJECT ENGINEER: T. L. Evans

CURRENT CONTRACT PERIOD:

FROM: 8/1/80 **TO:** 9/30/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: On-Site Data Hardware/7.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	43800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. Provide site application software for On-Site Data Acquisition System (ODAS).
2. Provide for installation, wiring, and checkout of ODAS and meteorological station.
3. Provide maintenance for weather station instruments for two years.
4. Allow data from photovoltaic project to be collected by Photovoltaic Reduction Center.

STATUS:

Contract placed on July 17, 1980. All hardware shipped to date.

DATE PREPARED: 8/26/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Trough, Mirror Laminated
CONTRACT NUMBER: 62-5044

CONTRACTOR (NAME AND ADDRESS):
PPG Industries, Inc.
New Products Div.
1 Gateway Center
Pittsburgh, PA 15222
TELEPHONE: (412) 434-2644
PRINCIPAL INVESTIGATOR: C. R. Frownfelter

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-3773
PROJECT ENGINEER: S. B. Martin

CURRENT CONTRACT PERIOD:
FROM: 8/1/80 **TO:** 1/1/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator Manufacturing Development /5.2

CONTRACT FUNDING:

FY	$	SOURCE:
80	26500	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To provide prototype laminated formed glass parabolic trough mirrors.

DELIVERABLES:

Hardware

STATUS:

Total Contract value - $49,600

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: An Integrated Back Contact Solar Cell for Use in Concentrated Sunlight

CONTRACT NUMBER: 13-2304

CONTRACTOR (NAME AND ADDRESS):
Purdue University
School of Electrical Engineering
West Lafayette, IN 47907

TELEPHONE: (317) 749-2467

PRINCIPAL INVESTIGATOR: Richard Schwartz

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 67185

TELEPHONE: (505) 844-2351

PROJECT ENGINEER: C. M. Garner

CURRENT CONTRACT PERIOD:
FROM: 1/18/79 **TO:** 1/18/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 149800	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

To perform analysis of IBC cells produced at Sandia Laboratories and suggest design changes to improve the performance of the cells.

To provide computer simulation of solar cell performance on request.

To formalize the design for a combination silicon-germanium double junction cell.

DELIVERABLES:

Technical Report

STATUS:

Completed one dimensional solution to transport equations including high doping effects.

In process of bringing on line a two dimensional solution to transport equations including high doping effects.

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Photovoltaic/Thermal Analysis
CONTRACT NUMBER: 62-8114

CONTRACTOR (NAME AND ADDRESS):
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC
27709
TELEPHONE: (919) 541-5825
PRINCIPAL INVESTIGATOR: Richard Whisnant

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-2130
PROJECT ENGINEER: M. Rios

CURRENT CONTRACT PERIOD:
FROM: 7/21/80 **TO:** 9/21/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Conceptual Design and Optimization /1.2

CONTRACT FUNDING:

FY	$	SOURCE
80	44890	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To characterize some thermal loads in the Service, Commercial, Institutional and Industrial (SCII) sectors and correlate them with the most promising applications for PV utilization for the purpose of providing guidance for a PV/T analysis and for PV/T collector development.

DELIVERABLES:

Report of the Analysis

STATUS:

Study in progress

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Efficiency Improvement Study for GaAs Solar Cells

CONTRACT NUMBER: 49-1792

CONTRACTOR (NAME AND ADDRESS):
Rockwell International
Electronics Research Center
P. O. Box 1085
Thousand Oaks, CA 91360

TELEPHONE: (805) 498-4545

PRINCIPAL INVESTIGATOR: John Cape

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-9677

PROJECT ENGINEER: J. J. Wiczer

CURRENT CONTRACT PERIOD:
FROM: 4-1-80 **TO:** 4-1-81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Devices /4.2

CONTRACT FUNDING:

FY	$	SOURCE
80	375000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To study efficiency correlation with GaAs substrate properties.

DELIVERABLES:

Technical Report

STATUS:

Work in progress

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/25/80

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Devise GaAs Array Development
CONTRACT NUMBER: 07-7274

CONTRACTOR (NAME AND ADDRESS):
Rockwell International
Electronics Research Center
1049 Camino dos Rios
P.O.Box 1085, Thousand Oaks, CA 91360
TELEPHONE: (805) 498-4545
PRINCIPAL INVESTIGATOR: John Cape

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-9677
PROJECT ENGINEER: J. J. Wiczer

CURRENT CONTRACT PERIOD:
FROM: 6/15/78 **TO:** 8/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Devices /4.2

CONTRACT FUNDING:

FY	$	SOURCE:
78	524800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

A demonstration of dense array concept for central receiver photovoltaic power generation

DELIVERABLES:

Final Report

STATUS:

Complete

DATE PREPARED: 8/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: San Bernardino West Side Community Development Corp. Project
CONTRACT NUMBER: 46-3066

CONTRACTOR (NAME AND ADDRESS):
San Bernardino West Side
Community Dev. Corp.
1736 West Highland Ave.
San Bernardino, CA 92411
TELEPHONE: (714) 887-2546
PRINCIPAL INVESTIGATOR: Marvin Stary

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185
TELEPHONE: (505) 844-7790
PROJECT ENGINEER: D. E. Haskins

CURRENT CONTRACT PERIOD:
FROM: 11/29/79 **TO:** 8/31/80

PROBABLE PROJECT COMPLETION DATE: 8/31/81

AREA/TASK: Project Support /8.2

CONTRACT FUNDING:		SOURCE:
FY 80	$ 308200	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this project is to fabricate and install a 35 kW peak photovoltaic (PV) power system at the San Bernardino West Side Community Development Corporation's industrial site in San Bernardino, CA. The PV power system design shall be as defined in the Contractor's Phase I Final Report, Detailed Drawing Package, and Phase II Updated Plan prepared as a part of the requirements for Contract No. 46-3066.

The Contractor shall operate the photovoltaic system and collect performance data in accordance with the Uniform Data and Information System previously furnished to the Contractor (Contract 46-3066). These data shall be furnished to Sandia for evaluation purposes and incorporation into the DOE Data Reduction Center for distribution to other photovoltaic system designers and data users.

DELIVERABLES:

Final Report

STATUS:

Phase I - Design

Phase II - Fabrication (in negotiations); will be new contract #62-8225.

DATE PREPARED: 9/24/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Simplified Design Methodologies

CONTRACT NUMBER: 13-2281

CONTRACTOR (NAME AND ADDRESS):

Science Applications, Inc.
McLean, Virginia

TELEPHONE: (703) 821-4495

PRINCIPAL INVESTIGATOR: S. K. Young

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2433

PROJECT ENGINEER: G. J. Jones

CURRENT CONTRACT PERIOD:

FROM: 2/22/79 TO: 8/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Engineering Support/1.3

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 296800	DOE AN-15
FY 80	$ 41000	DOE AN-15
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

The contractor is to study conceptual and detailed designs for photovoltaic systems published to date. Using these as guidance and drawing on experience of other technologies, a simplified methodology for the use of architects and engineers in the design of grid-connected photovoltaic systems is to be developed. Heavy involvement and review by the A&E community is required.

DELIVERABLES:

Design Handbook

Technical Report, SAND80-7147

STATUS:

Methodology has been evaluated by numerous architects and A&E firms. Revisions are in progress. Completion of Draft handbook scheduled for mid-September.

DATE PREPARED: 8/27/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Parabolic Trough with Sagged Glass

CONTRACT NUMBER: 42-7317

CONTRACTOR (NAME AND ADDRESS):
Solarex Corporation
1335 Piccard Dr.
Rockville, MD 20850

TELEPHONE: (301) 948-0202

PRINCIPAL INVESTIGATOR: Roy Gibson

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604

PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:

FROM: 11/1/79 TO: 8/31/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: Array Evaluation /6.2

CONTRACT FUNDING:

FY	$	SOURCE:
80	82000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To improve the design of the photovoltaic concentrator array developed under Phase I of PRDA-35. Improvements were to include better mirrors and a better receiver assembly.

DELIVERABLES:

Final Report

STATUS:

Improvements are being implemented.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/23/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Solar Cell Development

CONTRACT NUMBER: 46-2042B

CONTRACTOR (NAME AND ADDRESS): Solarex Corporation 1335 Piccard Dr. Rockville, MD 20850	**DIRECTING ORGANIZATION AND ADDRESS:** Sandia National Laboratories Albuquerque, New Mexico 87185
TELEPHONE: (301) 948-0202	**TELEPHONE:** (505) 844-8979
PRINCIPAL INVESTIGATOR: John Wohlgemuth	**PROJECT ENGINEER:** H. T. Weaver

CURRENT CONTRACT PERIOD:

FROM: 7/1/80 **TO:** 1/1/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE
80	42000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Attach cells to unit assemblies

DELIVERABLES:

3 assemblies

STATUS:

In progress

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/17/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Cell Assembly Studies
CONTRACT NUMBER: 46-2259

CONTRACTOR (NAME AND ADDRESS):
Solarex Corporation
1335 Piccard Dr.
Rockville, MD 20850

TELEPHONE: (301) 948-0202
PRINCIPAL INVESTIGATOR: John Wohlgemuth

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 7/1/80 **TO:** 7/1/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 240000	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Develop methods for attaching silicon cells to heat sinks.

STATUS:

In progress

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/17/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Commercial Concentrator Module Development

CONTRACT NUMBER: 07-7168

CONTRACTOR (NAME AND ADDRESS):

Spectrolab
12500 Gladstone
Sylmar, CA

TELEPHONE: (213) 365-4611

PRINCIPAL INVESTIGATOR: Ron Opjorden

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5634

PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:

FROM: 05/01/78 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 10/31/80

AREA/TASK: Manufacturing Development/5.2

CONTRACT FUNDING:

FY	$	SOURCE:
78	140900	DOE AN-15
80	1170	

SUMMARY:

CONTRACT OBJECTIVES:

Under a photovoltaic 10 kW concentrator design development contract, Spectrolab designed a 1/2 parabola module which includes a compound eliptical concentrating secondary. Under this contract, they will redesign this concentrator for utilization in stand-alone applications of approximately 450 W_p. The redesign will incorporate two off axis primary half parabola concentrators, two secondary concentrator/photovoltaic elements mounted along the focal lines of the two primaries. The entire module will be mounted in a polar tracking orientation.

DELIVERABLES:

A prototype array has been delivered.

STATUS:

The prototype is awaiting assembly and testing at Sandia.

The draft final report has not yet been completed.

DATE PREPARED: 8/25/80

261

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: 10 kW Array Fabrication
CONTRACT NUMBER: 07-7266

CONTRACTOR (NAME AND ADDRESS):
Spectrolab
12484 Gladstone Ave.
Sylmar, CA 91342

TELEPHONE: (213) 365-4611
PRINCIPAL INVESTIGATOR: N. Grossman

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604
PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:
FROM: 7/10/78 **TO:** 12/1/79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
FY 78	$ 499000	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Fabrication of a 10 kilowatt array which utilizes an off-axis half-parabolic trough. The unit will be passively cooled. Azimuth tracking is accomplished by mounting the full 10 kW array on a carousel. Elevation tracking is achieved by pivot in the rows of troughs parallel to their longitudinal axis.

DELIVERABLES:

A 10 kilowatt array

STATUS:

Complete 12/79

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Cell Production Development CONTRACT NUMBER: 13-2358	
CONTRACTOR (NAME AND ADDRESS): Spectrolab 12500 Gladstone Ave. Sylmar, CA 91342 TELEPHONE: (213) 365-4611 PRINCIPAL INVESTIGATOR: Bill Taylor	DIRECTING ORGANIZATION AND ADDRESS: Sandia National Laboratories Albuquerque, New Mexico 87185 TELEPHONE: (505) 844-8979 PROJECT ENGINEER: H. T. Weaver
CURRENT CONTRACT PERIOD: FROM: 2/22/79 TO: 1/31/80	CONTRACT FUNDING: SOURCE: FY 79 $ 223800 DOE AN-15 FY ___ $ ___ ___ FY ___ $ ___ ___ FY ___ $ ___ ___ FY ___ $ ___ ___
PROBABLE PROJECT COMPLETION DATE:	
AREA/TASK: Silicon Cells /4.1	

SUMMARY:

CONTRACT OBJECTIVES:

To investigate the feasibility of using thick photoresist patterns with screen printing techniques for solar cell metallization.

DELIVERABLES:

Technical Report

Prototype cells

STATUS:

Complete. Final Report in print shop.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/17/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: IBC Cell Development
CONTRACT NUMBER: 49-2715

CONTRACTOR (NAME AND ADDRESS):
Spire Corporation
Patriots Park
Bedford, Massachusetts 01730

TELEPHONE: (617) 275-6000
PRINCIPAL INVESTIGATOR: John A. Minnucci

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 5/1/80 **TO:** 5/1/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	202800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Fabricate a silicon with metal contacts only on one side.

DELIVERABLES:

15 cells

STATUS:

In progress

DATE PREPARED: 9/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Advanced Cell Process Development
CONTRACT NUMBER: 13-3548

CONTRACTOR (NAME AND ADDRESS):
Spire Corporation
Patriots Park
Bedford, Mass. 01730

TELEPHONE: (617) 275-6000
PRINCIPAL INVESTIGATOR: John Minnuci

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979
PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 2/24/79 **TO:** 4/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE
79	206300	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Investigate relative performance of ion implanted cells vs cells fabricated using conventional diffusion methods.

DELIVERABLES:

50 cells

Technical Report

STATUS:

Contract complete -- need final report.

DATE PREPARED: 9/22/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Solar Cell Development

CONTRACT NUMBER: 46-2042C

CONTRACTOR (NAME AND ADDRESS):

Spire Corporation
Patriots Park
Bedford, Mass. 01730

TELEPHONE: (617) 275-6000

PRINCIPAL INVESTIGATOR: John A. Minnucci

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-8979

PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:

FROM: 7/1/80 **TO:** 1/1/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon cells /4.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 74000	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Put cells onto linear assembly.

DELIVERABLES:

4 assemblies

STATUS:

In progress

DATE PREPARED: 9/23/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: CPC Concentrator

CONTRACT NUMBER: 07-7167

CONTRACTOR (NAME AND ADDRESS):

SunTrac Corp.
1674 South Wolf Road
Wheeling, Illinois 60090

TELEPHONE: (312) 299-1080

PRINCIPAL INVESTIGATOR: J. Frommeyer

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5634

PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:

FROM: 2/13/78 **TO:** 2/28/80

PROBABLE PROJECT COMPLETION DATE: 10/31/80

AREA/TASK: Manufacturing Development /5.2

CONTRACT FUNDING:

FY	$	SOURCE:
78	237400	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

SunTrac Corporation is a company which independently developed and manufactured a photovoltaic concentrator array for oil well cathodic protection a few years ago. The array design incorporated a conical reflector with a concentration ratio of about 10 and a concentrator matrix formed by such conical concentrators enclosed in an acrylic sphere. It is a 2-axis tracking concentrator. Under this contract, SunTrac is developing a new enlarged version of this same array.

DELIVERABLES:

Final report

Prototype array received.

STATUS:

Draft final report is under review.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/23/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: 2000:1 Fresnel Lens

CONTRACT NUMBER: 13-0299

CONTRACTOR (NAME AND ADDRESS):
Swedlow, Inc.
12122 Western Ave.
Garden Grove, CA 92645

TELEPHONE: (714) 893-7531

PRINCIPAL INVESTIGATOR: Dave Holdridge

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7604

PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:

FROM: 8/10/78 **TO:** 10/10/79

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Concentrator Manufacturing Development /5.2

CONTRACT FUNDING:

		SOURCE:
FY 78	$ 49300	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Development of a Fresnel lens capable of producing concentration ratios of 125, 250, 500, 750, 1000, 1250, 1500, 1750, and 2000 suns over a target area of 1" diameter. At each of these concentration ratios, the flux uniformity at the target shall be flat within 5%. These 54" diameter lenses will facilitate testing GaAs and other cells designed to operate at high concentration ratios.

DELIVERABLES:

Five lenses of the above design

STATUS:

Extensive design analysis showed that the above objectives were not feasible, so the project was halted before attempting to fabricate the lenses.

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Laminated Glass-Acrylic Fresnel Lens Development
CONTRACT NUMBER: 13-5165

CONTRACTOR (NAME AND ADDRESS):
Swedlow
12122 Western Ave.
Garden Grove, CA 92645

TELEPHONE: (714) 893-7531
PRINCIPAL INVESTIGATOR: Lawrence A. Matalon

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2130
PROJECT ENGINEER: C. B. Stillwell

CURRENT CONTRACT PERIOD:
FROM: 9/25/79 **TO:** 7/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 106500	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

To develop a laminated glass/plastic Fresnel lens for use in point focus photovoltaic concentrators.

DELIVERABLES:

1. 50 point focus lenses
2. Monthly reports
3. Final reports

STATUS:

Lens delivery to be 8/8/80

DATE PREPARED: 8/26/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Solid Acrylic Lens Production Development
CONTRACT NUMBER: 13-5166

CONTRACTOR (NAME AND ADDRESS):
Swedlow
12122 Western Ave.
Garden Grove, CA 92645

TELEPHONE: (714) 893-7531
PRINCIPAL INVESTIGATOR: Craig Childers

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2136
PROJECT ENGINEER: C. B. Stillwell

CURRENT CONTRACT PERIOD:
FROM: 9/15/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	101900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

To design and fabricate a 5 x 5 lens parquet of solid acrylic Fresnel point focus lenses for use in a point focus photovoltaic concentrator module

DELIVERABLES:

1. 10 ea single lenses
2. 4 ea 5 x 5 lens parquet
3. Monthly reports
4. Final report

STATUS:

1. 10 ea single lenses delivered

DATE PREPARED: 8/26/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Fresnel Lens Production Development
CONTRACT NUMBER: 13-8702

CONTRACTOR (NAME AND ADDRESS): Swedlow, Inc. 12122 Western Ave. Garden Grove, CA 92645	DIRECTING ORGANIZATION AND ADDRESS: Sandia National Laboratories Albuquerque, New Mexico 87185
TELEPHONE: (714) 893-7531	TELEPHONE: (505) 844-7604
PRINCIPAL INVESTIGATOR: Dave Holdridge	PROJECT ENGINEER: B. D. Shafer

CURRENT CONTRACT PERIOD:
FROM: 5/25/79 TO: 12/1/79
PROBABLE PROJECT COMPLETION DATE:
AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	49500	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Development of processes for the fabrication of parquets of point focus acrylic Fresnel lenses for use in photovoltaic concentrator arrays.

DELIVERABLES:

Five large area (30 ft^2) multiple parquets of photovoltaic concentrator lenses.

STATUS:

Completed 12/1/79; parquets were fabricated and delivered.

DATE PREPARED: 9/24/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: X Ray Topographic Studies
CONTRACT NUMBER: 42-5887

CONTRACTOR (NAME AND ADDRESS):
Texas A & M
Electrical Engineering Dept
Inst. for Solid State Electronics
College Station, TX 77843
TELEPHONE: (713) 845-7030
PRINCIPAL INVESTIGATOR: Donald L. Parker

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, NM 87185
TELEPHONE: (505) 844-3274
PROJECT ENGINEER: R. E. Anderson

CURRENT CONTRACT PERIOD:
FROM: 11/1/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 12/31/80

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE
80	21000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

(1) Build x-ray topographic camera for use with 5" silicon wafers. Improve resolution in both TV camera and films.

(2) Apply camera to identification of device processing problems such as: virgin wafer damage, defects introduced by thermal cycling, defects introduced by oxidation, defects introduced by diffusion and ion implementation, growth and quenching of defects. Fabrication of wafers is done at SNLA.

(3) Provide routine x-ray topograph service.

DELIVERABLES:

Only data

STATUS:

Objective 1 completed.

Objectives 2 & 3 are ongoing and will continue to completion of contract.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/15/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Cost Methodology Development
CONTRACT NUMBER: 46-5760

CONTRACTOR (NAME AND ADDRESS):
Theodore Barry & Associates
1520 Wilshire Blvd.
Los Angeles, CA 90017

TELEPHONE: (213) 413-6080
PRINCIPAL INVESTIGATOR: R. J. Bullemer

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2433
PROJECT ENGINEER: G. J. Jones

CURRENT CONTRACT PERIOD:
FROM: 1/7/80 **TO:** 11/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Conceptual Design and Optimization /1.2

CONTRACT FUNDING:

FY	$	SOURCE
80	273300	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this study is to provide a method for estimating and reporting all Balance of System costs incurred in production of photovoltaic systems and at the construction site.

Task I, Program development: (1) Survey of User Needs (2) Review of Current Procedures and Plans (3) Development of Approaches (4) Work Plan Report

Task II, Balance of system model development: (1) Cost Account Catalog Expansion (2) Alternative Indirect Requirements Matrices (3) Marketing and Distribution Model Modification (4) Computer Analysis (5) Model Development Report

Task III, Construction Cost Procedures: (1) Review of Application Experiments (2) Development of Cost Account Structure (3) Preparation of Cost Guide (4) Preparation of Reporting Manual

Task IV, Design program to automate marketing, distribution and financial submodels. Deliverables: (1) Design Document (2) Source Code (3) User Manual (4) Seminar

DELIVERABLES:

Monthly Status reports
Oral Quarterly reports
Final report

STATUS:

Samics Modification and Cost Guide are complete.
Computerization of Marketing and Distribution Model is underway.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/27/80

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JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Photovoltaic System Cost Elements
CONTRACT NUMBER: 49-8435

CONTRACTOR (NAME AND ADDRESS):
Theodore Barry & Associates
1520 Wilshire Blvd.
Los Angeles, CA 90017

TELEPHONE: (213) 413-6080
PRINCIPAL INVESTIGATOR: Bob Bullemer

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7825
PROJECT ENGINEER: J. L. Jackson

CURRENT CONTRACT PERIOD:
FROM: 7/17/80 TO: 9/17/81

PROBABLE PROJECT COMPLETION DATE: 9/30/81

AREA/TASK: Engineering Support /1.3

CONTRACT FUNDING:

FY	$	SOURCE:
80	202900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. Select candidate PV systems for given structures in the residential and intermediate sectors.
2. Estimate post-factory PV costs for candidate systems assuming new construction.
3. Estimate post-factory PV costs for candidate systems assuming retrofit of PV systems.
4. Propose cost reduction techniques and assess their impact on cost estimates developed for new and retrofit construction.

DELIVERABLES:

Final report due two months after conclusion of technical work.

STATUS:

Work in progress.

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: High Concentration Module Development
CONTRACT NUMBER: 13-9436

CONTRACTOR (NAME AND ADDRESS):
Thermo-Electron
101 First Ave.
Waltham, MA 02154

TELEPHONE: (617) 890-8700
PRINCIPAL INVESTIGATOR: R. Scharlack

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87165

TELEPHONE: (505) 844-5634
PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:
FROM: 12/6/79 **TO:** 12/31/80

PROBABLE PROJECT COMPLETION DATE: 1/31/80

AREA/TASK: Concentrator Concept Development /5.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	275900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The two primary objectives are

(1) demonstrate the feasibility of a high concentration and high efficiency PV module using domed acrylic fresnel lenses and Si cells.

(2) investigate the possibility of injection molding of domed acrylic lenses.

DELIVERABLES:

A prototype module will be delivered.

STATUS:

Lens tooling is being fabricated.

Design is complete.

DATE PREPARED: 8/26/80

BEST DOCUMENT AVAILABLE

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: PV Residential Retrofit
CONTRACT NUMBER: 62-0229

CONTRACTOR (NAME AND ADDRESS):
Total Environmental Action
Church Hill
Harrisville, NH 03450

TELEPHONE: (603) 827-3374
PRINCIPAL INVESTIGATOR: D. E. Mahone

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7825
PROJECT ENGINEER: J. L. Jackson

CURRENT CONTRACT PERIOD:
FROM: 8/11/80 TO: 10/11/80

PROBABLE PROJECT COMPLETION DATE: 10/11/80

AREA/TASK: Applications Analysis /1.1

CONTRACT FUNDING:

FY	$	SOURCE:
FY 80	$ 228044	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

1. Review existing literature and characterize existing residential structures in NE, SE, & SW U.S.
2. Select representative residential structures from each region as well as appropriate PV systems for retrofitting to these structures.
3. Propose detailed retrofitting schemes and estimate resultant costs.
4. Optimize installation techniques and equipment locations. Estimate potential market.

DELIVERABLES:

Final report due two months after conclusion of technical effort.

STATUS:

Work in progress.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Fabricate and Deliver an Azimuth Tracking Array
CONTRACT NUMBER: 62-6536

CONTRACTOR (NAME AND ADDRESS):
University of Arizona
Water Resources Center
Tucson, AZ 85721

TELEPHONE: (602) 626-1808
PRINCIPAL INVESTIGATOR: C. B. Cluff

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5634
PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:
FROM: 8/1/80 **TO:** 2/28/81

PROBABLE PROJECT COMPLETION DATE: 5/31/81

AREA/TASK: Concentrator Concept Development /5.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 40000	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

To fabricate and test a low-concentration (5-10X) array that utilizes flat plate modules and azimuth tracking via flotation on a shallow pond.

DELIVERABLES:

A prototype array.

STATUS:

Contract placed on 8/21/80.

DATE PREPARED: 9/23/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Solar Cell Research
CONTRACT NUMBER: 49-2603

CONTRACTOR (NAME AND ADDRESS): University of California Campus Research Office M11 Wheeler Hall Berkeley, CA 94720 TELEPHONE: (415) 642-0540 PRINCIPAL INVESTIGATOR: Dick White	DIRECTING ORGANIZATION AND ADDRESS: Sandia National Laboratories Albuquerque, New Mexico 87185 TELEPHONE: (505) 844-8979 PROJECT ENGINEER: H. T. Weaver

CURRENT CONTRACT PERIOD:
FROM: 5/1/80 TO: 5/1/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	63500	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop a novel cell for application in high concentration systems.

STATUS:

In progress

BEST DOCUMENT AVAILABLE

DATE PREPARED: 9/17/80

278

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Advanced Silicon Concentrator Cell Development
CONTRACT NUMBER: 13-2303

CONTRACTOR (NAME AND ADDRESS):
University of Florida
Dept. of Electrical Engineering
Gainesville, Florida 32611

TELEPHONE: (904) 392-4921
PRINCIPAL INVESTIGATOR: Jerry Fossum

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-6137
PROJECT ENGINEER: R. D. Nasby

CURRENT CONTRACT PERIOD:
FROM: 3/01/78 **TO:** 5/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE:
79	87700	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The purpose of this project is to develop more efficient Si concentrator solar cells. The initial and primary emphasis has been to understand the operation of a ptnnt back surface field solar cell and devise methods to increase the cell conversion efficiency.

DELIVERABLES:

Technical Report

STATUS:

Completed 05/80.

DATE PREPARED: 8/18/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Advanced Silicon Concentrator Cell Development

CONTRACT NUMBER: 28-1161

CONTRACTOR (NAME AND ADDRESS):
University of Florida
Dept. of Electrical Engineering
Gainesville, Florida 32611

TELEPHONE: (904) 392-4921

PRINCIPAL INVESTIGATOR: Jerry G. Fossum

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-6137

PROJECT ENGINEER: R. D. Nasby

CURRENT CONTRACT PERIOD:

FROM: 6/1/80 **TO:** 6/1/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Silicon Cells /4.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	60000	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

1. To give analytical support for concentrator cell development.
2. Development of p^+-n-n^+ solar cell.
3. Experimentally and theoretically examine some new design concepts, esp. HLE solar cell.

DELIVERABLES:

Technical report

STATUS:

Active

DATE PREPARED: 8/18/80

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Amorphous Metallization for Solar Cells

CONTRACT NUMBER: 49-1664

CONTRACTOR (NAME AND ADDRESS):
University of Wisconsin
Dept. of Elect. Eng.
Madison, WI 53706

TELEPHONE: (608) 262-9693

PRINCIPAL INVESTIGATOR: John Wiley

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2609

PROJECT ENGINEER: R. J. Chaffin

CURRENT CONTRACT PERIOD:
FROM: 1-22-80 **TO:** 9-30-80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Devices /4.2

CONTRACT FUNDING:

FY	$	SOURCE:
80	35100	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Develop amorphous metals for semiconductor devices. The use of these metals will result in improved corrosion resistance, electromigration resistance and form excellent diffusion barriers.

DELIVERABLES:

Samples and report

STATUS:

Will be complete 9/30/80

DATE PREPARED: 8/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: 400X Fresnel/AlGaAs Module Development
CONTRACT NUMBER: 42-7248

CONTRACTOR (NAME AND ADDRESS):
Varian Associates
611 Hansen Way
Palo Alto, CA 94363

TELEPHONE: (415) 493-4000 X-4186
PRINCIPAL INVESTIGATOR: R. J. Owen

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7825
PROJECT ENGINEER: J. L. Jackson

CURRENT CONTRACT PERIOD:
FROM: 2/22/80 **TO:** 10/31/80

PROBABLE PROJECT COMPLETION DATE: 10/31/80

AREA/TASK: Array Design and Fabrication /6.1

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 190200	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

1. Design PV concentrator module employing high concentration, curved facet, acrylic Fresnel lenses, high efficiency AlGaAs/GaAs cells and jet impingement cell cooling subsystem.
2. Design goals are 14% efficiency, 20 year life and cost effectiveness.
3. Develop preliminary, conceptual array design employing selected module configuration.

DELIVERABLES:

1. Two identical prototype modules. One will be delivered to Sandia for further testing.
2. Final report deliverable 2 months following completion of technical effort.

STATUS:

1. Preliminary Varian testing indicates an efficiency of 16.4% at a coolant temperature of 50°C.

DATE PREPARED: 9/24/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Novel Concentrator Cell Development
CONTRACT NUMBER: 07-6953A

CONTRACTOR (NAME AND ADDRESS):
Varian Associates
Central Research Laboratories
Palo Alto, California

TELEPHONE: (415) 493-4000 λ-2906
PRINCIPAL INVESTIGATOR: Ron Bell

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-9678
PROJECT ENGINEER: J. J. Wiczer

CURRENT CONTRACT PERIOD:
FROM: 2/31/79 **TO:** 3/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Devices /4.2

CONTRACT FUNDING:

FY	$	SOURCE
79	237800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Varian will investigate a 3 bandgap solar receiver and perform economic and performance benefit tradeoff studies. Varian will optimize the 2 bandgap spectral splitting receiver and investigate mechanical stacking technology of separate solar cells.

DELIVERABLES:

Final report received - SAND80-7072

DATE PREPARED: 8/22/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: GaAs Cell Production Development
CONTRACT NUMBER: 13-2357

CONTRACTOR (NAME AND ADDRESS):
Varian Associates
Central Research Labs.
Palo Alto, CA

TELEPHONE: (415) 493-4000 X-2906
PRINCIPAL INVESTIGATOR: Ron Bell

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-9677
PROJECT ENGINEER: J. J. Wiczer

CURRENT CONTRACT PERIOD:
FROM: 12/15/78 **TO:** 1/31/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Devices /4.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	223800	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Varian shall develop methods for automated high throughput epitaxial growth of high performance GaAs concentrator cells. Varian will also develop the capability to process 100 sq. in./day of solar cells with a yield of greater than 50%. Varian will develop crystal growth technology for 2 in.-diameter GaAs crystal substrate material and explore the feasibility of 3 in.-diameter crystals.

DELIVERABLES:

Technical Report
SAND80-7066

STATUS:

Complete

DATE PREPARED: 8/22/80

TITLE: Beam Splitting Array Development
CONTRACT NUMBER: 13-0308

CONTRACTOR (NAME AND ADDRESS):
Varian Associates
611 Hansen Way
Palo Alto, CA 94303

TELEPHONE: (415) 493-4000/2906
PRINCIPAL INVESTIGATOR: R. L. Bell

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5634
PROJECT ENGINEER: E. C. Boes

CURRENT CONTRACT PERIOD:
FROM: 12/8/78 **TO:** 8/31/80

PROBABLE PROJECT COMPLETION DATE: 10/31/80

AREA/TASK: Concentrator Concept Development / 5.1

CONTRACT FUNDING:

FY	$	SOURCE:
78	223200	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

Varian will design a PV module which uses a spectral beam splitter and two cells with each optical concentrator. The cells will be silicon for the low energy portion and gallium arsenide for the high energy portion. An acrylic Fresnel lens will be used.

DELIVERABLES:

A ten unit (20 cell) prototype module will be delivered by 9/30/80.

STATUS:

The prototype is assembled and is undergoing testing at Varian.

The final report is being drafted.

DATE PREPARED: 8/26/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Accelerated Aging of GaAlAs Solar Cells
CONTRACT NUMBER: 13-5674

CONTRACTOR (NAME AND ADDRESS):
Varian Associates
Central Research Lab.
Palo Alto, CA

TELEPHONE: (415) 493-4000
PRINCIPAL INVESTIGATOR: Peter Borden

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-6407
PROJECT ENGINEER: C. E. Barnes

CURRENT CONTRACT PERIOD:
FROM: 7/12/79 **TO:** 10/15/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Devices /4.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	354200	DOE AN-15
80	50000	

SUMMARY:

CONTRACT OBJECTIVES:

Varian Associates will develop high temperature solar cell-package bonding techniques for special elevated temperature testing. Varian will fabricate 270 of these cells, 50 for delivery to Sandia, and 220 to be tested at Varian. These accelerated aging studies shall include: temperature cycling, corrosion experiments, ohmic contact investigations, electromigration tests, and tests at various illumination levels and temperatures.

DELIVERABLES:

Technical Report

STATUS:

Work Extension

DATE PREPARED: 8-20-80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Regional Residential Design Studies CONTRACT NUMBER: 07-6924	
CONTRACTOR (NAME AND ADDRESS): Westinghouse Electric Co. R&D Center Pittsburgh, PA TELEPHONE: (412) 256-7802 PRINCIPAL INVESTIGATOR: Paul Pittman	DIRECTING ORGANIZATION AND ADDRESS: Sandia National Laboratories Albuquerque, New Mexico 87185 TELEPHONE: (505) 844-2433 PROJECT ENGINEER: G. J. Jones
CURRENT CONTRACT PERIOD: FROM: 8/15/77 TO: 10/31/79	CONTRACT FUNDING: SOURCE: FY 79 $ 319700 DOE AN-15 FY ___ $ ___ FY ___ $ ___
PROBABLE PROJECT COMPLETION DATE: Completed	FY ___ $ ___
AREA/TASK: Engineering Support/1.3	FY ___ $ ___

SUMMARY:

CONTRACT OBJECTIVES:

This work involves detailed tradeoff analyses of the numerous photovoltaic system options suitable for on-site residential applications in the 1986 time frame. All of the calculations will be done as a function of insolation and space conditioning load as well as architectural variance reflecting the sites chosen to represent the regions within the continental United States. Those systems in each region judged to be the most promising will be incorporated into the preliminary design of residential test facilities. Institutional and technical concerns will be evaluated and recommended priorities as to regions, test facility types, and test systems given.

DELIVERABLES:

Executive Summary - SAND78-7040 issued 8/15/79

STATUS:

Final Report Issued - SAND78-7040, Vols. 1 & 2.

BEST DOCUMENT AVAILABLE

DATE PREPARED: 8/27/80

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JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Construction of a 50 kVA Power Conditioning Unit for Photovoltaic System

CONTRACT NUMBER: 07-6940

CONTRACTOR (NAME AND ADDRESS):

Westinghouse AED
Lima, Ohio

TELEPHONE: (419) 226-3159

PRINCIPAL INVESTIGATOR: Wayne Niederjohn

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5206

PROJECT ENGINEER: C. M. Coats

CURRENT CONTRACT PERIOD:

FROM: 12/01/77 **TO:** 1/31/80

PROBABLE PROJECT COMPLETION DATE: 12/1/80

AREA/TASK: Power Conditioning and Control /2.2

CONTRACT FUNDING:

FY	$	SOURCE:
78	372400	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

This program covers the design, development, fabrication, and testing of a 40-50 kVA power conditioning unit (PCU) for photovoltaic power systems. The PCU includes a high efficiency, low tare loss DC to AC self-commutated inverter and a power system controller (PSC). The PSC provides overall electrical system interface control relating to maximum power tracking from the solar array, utility line paralleling, DC power storage/utilization and load demands.

DELIVERABLES:

Final Report due 9/80

STATUS:

Completed

DATE PREPARED: 9/15/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Engineering Study of Photovoltaic Utility Customer Interface
CONTRACT NUMBER: 13-3228

CONTRACTOR (NAME AND ADDRESS): Westinghouse Electric Corporation Advanced Systems Technology East Pittsburgh, Pennsylvania	**DIRECTING ORGANIZATION AND ADDRESS:** Sandia National Laboratories Albuquerque, New Mexico 87185
TELEPHONE: (412) 824-9100	**TELEPHONE:** (505) 844-2387
PRINCIPAL INVESTIGATOR: Vic Wilreker	**PROJECT ENGINEER:** K. L. Biringer

CURRENT CONTRACT PERIOD:
FROM: 02/28/79 **TO:** 04/30/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Applications Analysis/1.1

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 248800	DOE AN-15
FY 80	$ 38000	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

The objective of this work is to analyze the problems associated with the interconnection of an on-site photovoltaic system with the electric utility grid.

The task areas to be studied include:

1. Problem definition
2. Technical considerations
3. Economic considerations
4. Legal and jurisdictional considerations
5. Determination of the economic and operational values of dispersed residential PV systems for the electric utility grid.

CONTRACT STATUS:

Completed 04/80

Final Report changes in progress, SAND80-7061

DATE PREPARED: 8/26/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Production Engineering of 62.5 kW Inverter
CONTRACT NUMBER: 13-5169

CONTRACTOR (NAME AND ADDRESS):

Westinghouse AED
Lima, Ohio

TELEPHONE: (419) 226-3159
PRINCIPAL INVESTIGATOR: Wayne Niederjohn

DIRECTING ORGANIZATION AND ADDRESS:

Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-5206
PROJECT ENGINEER: C. M. Coats

CURRENT CONTRACT PERIOD:
FROM: 6-13-79 **TO:** 1-31-81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Power Conditioning and Control /2.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	305400	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

This program is for additional design engineering and drafting necessary to convert the 50 KVA prototype PCU design developed under Contract 07-6940 into a production design rated at 62.5 KVA suitable for field use. The upgraded design will incorporate the following modifications:

Automatic utility tie break upon loss of utility power and automatic reclosing when utility power returns

Modification to enable parallel operation of up to 8 production PCU's.

Three 62.5 KVA production PCU's will be built and shipped and the existing 50 KVA prototype will be retrofitted with final design PWB's and upgraded to 62.5 KVA.

DELIVERABLES:

Hardware

Design report

STATUS:

On Schedule

290

DATE PREPARED: 9/15/80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Breadboard of 10 kW Chopper Controlled Line Commutated Inverter
CONTRACT NUMBER: 13-8786

CONTRACTOR (NAME AND ADDRESS): Westinghouse AED Lima, Ohio **TELEPHONE:** (419) 226-3159 **PRINCIPAL INVESTIGATOR:** W. M. Niederjohn	**DIRECTING ORGANIZATION AND ADDRESS:** Sandia National Laboratories Albuquerque, NM 87185 **TELEPHONE:** (505) 844-3043 **PROJECT ENGINEER:** D. R. Smith

CURRENT CONTRACT PERIOD:
FROM: 9/15/79 **TO:** 10/1/80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Power Conditioning and Control /2.2

CONTRACT FUNDING:

FY	$	SOURCE:
79	47900	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The purpose of this work is to design and construct in breadboard form a 10 kW line-commutated inverter with a chopper-controlled input. The proposed concept utilizes a pulse width modulated chopper to produce a 120 Hz ripple current that is switched into the utility grid by a line-commutated SCR output bridge.

STATUS:

Breadboard design completed.

Final report in preparation.

DATE PREPARED: 11/12/80

BEST DOCUMENT AVAILABLE

291

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Economic Analysis of PV Systems
CONTRACT NUMBER: 62-0215

CONTRACTOR (NAME AND ADDRESS):
Westinghouse Electric Corp.
700 Braddock Ave.
East Pittsburg, PA 15112

TELEPHONE: (412) 256-2846
PRINCIPAL INVESTIGATOR: W. J. Hobbs

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-7825
PROJECT ENGINEER: J. L. Jackson

CURRENT CONTRACT PERIOD:
FROM: 5/1/80 **TO:** 9/1/80

PROBABLE PROJECT COMPLETION DATE: 10/30/80

AREA/TASK: Applications Analysis/1.1

CONTRACT FUNDING:		SOURCE:
FY 80	$ 49000	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

1. Development and description of PV system configurations and operating schemes for: PV only, PV/Battery under utility control, PV/Battery under customer control.
2. Determine PV system performance including power flows and energy summaries, and calculation of PV system value in terms of displaced electric utility operating and capital costs.
3. Limited analysis of cost/benefit ratios and impacts of PV market penetration levels.

DELIVERABLES:

Final report due two months after completion of technical reports.

STATUS:

Work in progress. Final set of calculations being run.

DATE PREPARED: 9/24/80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Engineering Test Development Support

CONTRACT NUMBER: 49-1532

CONTRACTOR (NAME AND ADDRESS):
Wyle Laboratories
7800 Governors Drive West
Huntsville, AL 35802

TELEPHONE: (205) 837-4411

PRINCIPAL INVESTIGATOR: S. L. Patrick

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2433

PROJECT ENGINEER: G. J. Jones

CURRENT CONTRACT PERIOD:

FROM: 03/19/80 TO: 03/19/81

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Array Technology /2.1

CONTRACT FUNDING:

FY	$	SOURCE:
80	78200	DOE AN-15

SUMMARY:

CONTRACT OBJECTIVES:

The contractor shall provide engineering, testing and procedure development to the hardware development activities as follows:

Task 1 - Develop and document test procedures for flat plate and concentrating collectors employing active cooling and aid in developing procedures for concentrating collectors in general.

Task 2 - Develop testing procedures for power conditioning equipment in cooperation with Sandia personnel.

Task 3 - Provide engineering support in the design and specification of equipment for use in collector evaluation.

Task 4 - Provide environmental testing of photovoltaic collectors as may be required.

Task 5 - Provide testing, monitoring and reporting support that may be required by System Application Experiments especially in the area of sensors and transducers.

DELIVERABLES:

Final report

STATUS:

Work on the test methodologies is currently underway. Backup testing capability has not yet been utilized.

DATE PREPARED: 8/27/80

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Pulsed Solar Simulator
CONTRACT NUMBER: 62-1630

CONTRACTOR (NAME AND ADDRESS):
Xenon Corporation
66 Industrial Way
Wilmington, MA 01887

TELEPHONE: (617) 658-8940
PRINCIPAL INVESTIGATOR: Louis R. Paniko

DIRECTING ORGANIZATION AND ADDRESS:
Sandia National Laboratories
Albuquerque, New Mexico 87185

TELEPHONE: (505) 844-2609
PROJECT ENGINEER: R. J. Chaffin

CURRENT CONTRACT PERIOD:
FROM: 7-18-80 **TO:** 9-30-80

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK: Advanced Devices /4.2

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 58000	DOE AN-15
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

CONTRACT OBJECTIVES:

Develop 1000 sun, AM 1.5, pulsed solar simulator

DELIVERABLES:

Report + Solar Simulator

STATUS:

Contract placed in July 1980; Delivery expected 12/80.

DATE PREPARED: 8/22/80

JET PROPULSION LABORATORY

Photovoltaics Technology Development and Applications Lead Center

295

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE:

CONTRACT NUMBER: 955434

CONTRACTOR (NAME AND ADDRESS):

AEROSPACE CORPORATION
P.O. Box 92957
Los Angeles, CA 90009

TELEPHONE: (213) 648-7040

PRINCIPAL INVESTIGATOR: Stan Leonard

DIRECTING ORGANIZATION AND ADDRESS:

JPL-Photovoltaic TD&A Lead Center
4800 Oak Grove Drive
Pasadena, CA 91103

TELEPHONE: (213) 577-9281

PROJECT ENGINEER: Cal Davis

CURRENT CONTRACT PERIOD:

FROM: 4/4/79 **TO:** 4/30/80

PROBABLE PROJECT COMPLETION DATE: 4/30/80

AREA/TASK: Planning Analysis & Integration

CONTRACT FUNDING:		SOURCE:
FY 79	$ 198K	PA&I
FY 80	$ 55K	PA&I
FY	$	
FY	$	
FY	$	

SUMMARY:

The final report entitled, Central Stations Applications Planning Activities and Supporting Studies, was received from Aerospace. The initial focus of the effort was the development and drafting of an Implementation Plan, later renamed to Requirements Document for those activities of the PV Program that are directed toward the application of PV technology in central station (utility) power generation plants.

When the major planning work had been completed, the emphasis of the project shifted to two supporting activities. The first of these was a program of data collection and analysis designed to provide additional information about the subset of the utility market identified as the initial target for PV penetration, i.e., the oil-dependent utilities (especially municipals) of the U.S. Sunbelt. The second supporting study was a series of interviews designed to ascertain utility industry opinions about the PV Program as it relates to central station applications.

These activities are completed and reported in the Final Report.

August 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE:

CONTRACT NUMBER: 955718

CONTRACTOR (NAME AND ADDRESS):

THE AEROSPACE CORPORATION
P,O, Box 92957
Los Angeles, CA 90009

TELEPHONE: (213) 648-7040
PRINCIPAL INVESTIGATOR: Stanley Leonard

DIRECTING ORGANIZATION AND ADDRESS:

JPL-Photovoltaic TD&A Lead Center
4800 Oak Grove Drive
Pasadena, CA 91103

TELEPHONE: (213) 577-9281
PROJECT ENGINEER: Calvin Davis

CURRENT CONTRACT PERIOD:
FROM: 4/25/80 **TO:** 3/30/81

PROBABLE PROJECT COMPLETION DATE: 3/30/81

AREA/TASK: Planning, Analysis and Integration

CONTRACT FUNDING:		**SOURCE:**
FY 80	$ 243K	PA&I
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

Analysis, Planning, Documentation Support for Photovoltaic Utility Applications.

Task 1. Program Support

A breakdown of projected subsystem/system costs for a PV power plant incorporating \$0.70/Wp (1980 \$) collector modules was prepared and forwarded to Howard Wright of the California Public Utilities Commission. Informal discussions were held on June 12 with members of the staff of the California Energy Commission. Topics included prospects for PV penetration of the central power (utility) market.

A two-page abstract was prepared for an invited paper, "Central Station PV Power: A Near-Term Generation Option for the Utility Industry", to be presented at the National Conference on Renewable Energy Technologies in Honolulu next December.

Task 2. Central Station Liaison

A meeting was held on June 11 with Sandia personnel to review on-going and planned systems studies related to central station applications area.

An Aerospace representative attended a meeting with Bechtel and Sandia on June 23 in San Francisco to review the progress by Bechtel on the subsystem optimization study.

Task 3. Evaluation of Oil Conservation Market

Work continues on the evaluation of the worth of PV plants to oil-dependent utilities and, in particular, on the first test case, which involves a 750 MW facility in the Southern California Edison (SCE) system.

Task 4. Analysis of Selected Issues

The analysis of self-commutated inverter technology was continued for this period so that a detailed comparison can be made with line-commutated designs.

August 1980

BEST DOCUMENT AVAILABLE

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE:

CONTRACT NUMBER: 955820

CONTRACTOR (NAME AND ADDRESS): MERIDIAN CORPORATION 5515 Cherokee Avenue, Suite 306 Alexandria, VA 22312 TELEPHONE: (703) 354-8424 PRINCIPAL INVESTIGATOR: Jim White	DIRECTING ORGANIZATION AND ADDRESS: JPL-Photovoltaic TD&A Lead Center 4800 Oak Grove Drive Pasadena, CA 91103 TELEPHONE: 577-9516 PROJECT ENGINEER: John Hesse
CURRENT CONTRACT PERIOD: FROM: 7/08/80 TO: 10/31/80	CONTRACT FUNDING:

CONTRACT FUNDING:		SOURCE:
FY 80	$ 20K	FPUP
FY	$	
FY	$	
FY	$	
FY	$	

PROBABLE PROJECT COMPLETION DATE: 10/31/80

AREA/TASK: FPUP Management Implementation

SUMMARY:

Development of Photovoltaic Marketing Strategy for Utility Sector. This is a directed effort by DOE, and supports early market development planning and strategy development in the central station application sector.

BEST DOCUMENT AVAILABLE

August 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE:

CONTRACT NUMBER: 955571

CONTRACTOR (NAME AND ADDRESS): PRC ENERGY ANALYSIS CO. 7600 Old Springhouse Road McLean, VA 22102 TELEPHONE: (202) 893-1820 PRINCIPAL INVESTIGATOR: Roger Ethier	DIRECTING ORGANIZATION AND ADDRESS: JPL-Photovoltaic TD&A Lead Center 4800 Oak Grove Drive Pasadena, CA 91103 TELEPHONE: 577-9523 PROJECT ENGINEER: Al Lawson

CURRENT CONTRACT PERIOD:

FROM: 11/06/79 TO: 2/29/80

PROBABLE PROJECT COMPLETION DATE: Terminated 7/80

AREA/TASK: FPUP Management Implementation

CONTRACT FUNDING:		SOURCE:
FY 80	$ 76K	FPUP
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

Analysis/Evaluation of Photovoltaic Systems Applications. This contract had the same purpose as its replacement (955677), but was cancelled for nonperformance.

BEST DOCUMENT AVAILABLE

August 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE:

CONTRACT NUMBER: 955677

CONTRACTOR (NAME AND ADDRESS):

SCIENCE APPLICATIONS, INC.
8400 Westpark Drive
McLean, VA 22102

TELEPHONE: (703) 821-5790

PRINCIPAL INVESTIGATOR: Tom Jaras

DIRECTING ORGANIZATION AND ADDRESS:

JPL-Photovoltaic TD&A Lead Center
4800 Oak Grove Drive
Pasadena, CA 91103

TELEPHONE: 577-9523

PROJECT ENGINEER: Al Lawson

CURRENT CONTRACT PERIOD:

FROM: 2/15/80 **TO:** 5/81

PROBABLE PROJECT COMPLETION DATE: 5/81

AREA/TASK: FPUP Management Implementation

CONTRACT FUNDING:		**SOURCE:**
FY 80	$ 100K	FPUP
FY 81	$ 98K	FPUP
FY	$	
FY	$	
FY	$	

SUMMARY:

Study of Commercial and Residential Markets for Photovoltaic Applications. This contract has supported selection of FPUP Cycle 4 Applications which best serve the commercialization function of the FPUP Program, and will serve the same role for a planned Cycle 5 in FY81.

August 1980

JET PROPULSION LABORATORY

Low-Cost Solar Array Project

301

TITLE: Development of Processes for the Production of Solar Grade Silicon CONTRACT NUMBER: 955491	
CONTRACTOR (NAME AND ADDRESS): AeroChem Research Laboratories P. O. Box 12 Princeton, NJ 08540 TELEPHONE: (609) 921-7070 PRINCIPAL INVESTIGATOR: Robert Gould	DIRECTING ORGANIZATION AND ADDRESS: Jet Propulsion Laboratory Low-Cost Solar Array Project (502-422) 4800 Oak Grove Drive Pasadena, CA 91109 TELEPHONE: (213) 354-7215 PROJECT ENGINEER: P. Seshan
CURRENT CONTRACT PERIOD: FROM: 10/79 TO: 2/81	CONTRACT FUNDING: SOURCE: FY 79 $ 37,500 DOE FY 80 $ 187,500 DOE FY ___ $ ___ FY ___ $ ___ FY ___ $ ___
PROBABLE PROJECT COMPLETION DATE: 2/81	
AREA/TASK: Silicon Material	

SUMMARY:

Part 1.

Develop process involving high temperature reactions of silicon halides with alkali metals for the production of solar-grade silicon in high volume at low cost.

Part 2.

Design, build, and operate a laboratory-scale, high-temperature, fast-flow reactor to study the kinetics of decomposition of silane and the dynamics of silicon particle formation and growth.

Status:

Part 1.

Completed on schedule. The work indicates that the process is capable of producing pure silicon. Sodium levels were below 10 ppma in most tests, showing good separation of by product sodium chloride from the product silicon.

Part 2.

Work started in June, 1980, and the first milestone (design, construct, and calibrate reactor by September 30, 1980) was completed on time. Work has since slowed because of delays in obligating funding.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Integrated Residential PV Array Development
CONTRACT NUMBER: 955893

CONTRACTOR (NAME AND ADDRESS):
AIA Research Corporation
1735 New York Avenue, N.W.
Washington, D.C. 20006

TELEPHONE: (202) 626-7500
PRINCIPAL INVESTIGATOR: G. Royal

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9118
PROJECT ENGINEER: R. Sugimura

CURRENT CONTRACT PERIOD:
FROM: 11/03/80 **TO:** 11/81

PROBABLE PROJECT COMPLETION DATE: 11/81

AREA/TASK: Engineering

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 100,000	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The Contractor shall develop an Integrated Residential Photovoltaic Array Design Package (PV-only), complete with detailed drawings to permit manufacture, fabrication and installation by a third party; and to provide a full-scale, representative section of a residential photovoltaic array, complete with electrical and mechanical interconnects and support hardware in accordance with the goals set forth in this Contract. Details of development relative to cell and encapsulation processing are not within the scope of the effort to be performed under this Contract.

Status:

New Contract.

September 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Solar Cell Fabrication & Testing

CONTRACT NUMBER: 955089

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corporation
Optical Coating Laboratory, Inc.
15251 E. Don Julian Road
City of Industry, CA 91746

TELEPHONE: (213) 968-6581

PRINCIPAL INVESTIGATOR: H. Yoo

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91103

TELEPHONE: (213) 354-2190

PROJECT ENGINEER: S. Hyland

CURRENT CONTRACT PERIOD:

FROM: 05/78 **TO:** 06/81

PROBABLE PROJECT COMPLETION DATE: 06/81

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE:
78	223,920	DOE
79	113,000	DOE
80	227,572	DOE
81	50,000	DOE

SUMMARY:

Fabrication of solar cells using reliable and reproducible processes; testing of the solar cells using standardized equipment and techniques; investigate, develop and utilize technologies appropriate and necessary for improving the efficiency of solar cells made from large area silicon sheets developed for Task II of LSA.

Status:

This contract is presently in Phase III which stresses the optimization of processing to maximize the efficiency of the solar cells from unconventional silicon sheets.

TITLE: Development of High Efficiency (14%) Solar Cell Array Modules

CONTRACT NUMBER: 955217

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corporation
(Optical Coating Laboratory, Inc.)
15251 E. Don Julian Rd.
City of Industry, CA 91746
TELEPHONE: (213) 968-6581
PRINCIPAL INVESTIGATOR: K. Ling

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91103
TELEPHONE: (213) 577-9563
PROJECT ENGINEER: J. Behm

CURRENT CONTRACT PERIOD:
FROM: 11/78 **TO:** 12/80

PROBABLE PROJECT COMPLETION DATE: 12/80

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
FY 79	$ 164,000	DOE
FY 80	$ 30,576	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Design a solar array module using high efficiency (16%) Air Mass 1 (AM1) solar cells; approximately 48 inches in length, 23 inches in width and the thickness as appropriate; each module to produce at least 90 watts of peak power at 28°C with an overall operating efficiency greater than or equal to 14%; and designed to achieve the lowest possible operating temperature, consistent with the high efficiency requirements.

Status:

This contract has been completed; the last item of documentation is scheduled for release shortly. The Final Report draft report has been review by JPL; the Final Report distribution is targeted for 12/1/80.

Significant contract accomplishments include the following:

1) A new large area 3 inch diameter P+NN+ solar cell has been delivered. Based on very limited experience average cell efficiencies of 13.5% has been achieved (AM1, 100 mw/cm^2, 28°C).

2) Unique solar cell interconnect soldering tooling was designed and developed during the contract. This equipment was so successful that the Contractor has ordered an automated version of this machine on their own funds to be used for future production work.

3) Six production modules were fabricated (approximately 2ft. X 4ft) which delivered approximately 11% conversion efficiency.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design, Fabrication, Test and Price Analysis of Third Generation Solar Cell Modules
CONTRACT NUMBER: 955409

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corporation
15251 E. Don Julian Rd.
City of Industry, CA 91746

TELEPHONE: (213) 968-6581
PRINCIPAL INVESTIGATOR: K. Ling

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9214
PROJECT ENGINEER: D. Runkle

CURRENT CONTRACT PERIOD:
FROM: 5/2/79 **TO:** 2/2/80

PROBABLE PROJECT COMPLETION DATE: 12/31/80

AREA/TASK: Module Production

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 65,000	DOE
FY 80	$ -0-	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Design, fabricate, test, qualify, deliver pre-production solar cell modules which comply with requirements of JPL Document 5101-16 Rev. A, entitled, "Block IV Solar Cell Modules Design, and Test Specification for Intermediate Load Center Applications." Prepare also a standardized price estimate for 10, 100, 1000 kW of modules delivered in 1980.

Status:

ASEC has completed delivery of modules to JPL and the module design is qualified. The standardized price analysis has been completed and the final report is the only outstanding deliverable.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Laboratory Services to the LSA Project Production Process and Equipment Area

CONTRACT NUMBER: 955423

CONTRACTOR (NAME AND ADDRESS):
Applied Solar Energy Corporation
(Optical Coating Laboratory, Inc.)
15251 E. Don Julian Rd.
City of Industry, CA 91746
TELEPHONE: (213) 968-6581
PRINCIPAL INVESTIGATOR: K. Ling

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109
TELEPHONE: (213) 577-9403
PROJECT ENGINEER: L. Sanchez

CURRENT CONTRACT PERIOD:
FROM: 3/79 **TO:** 3/80

PROBABLE PROJECT COMPLETION DATE: 9/81

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
79	135,000	DOE
80	-0-	DOE

SUMMARY:

Furnish labor and material, to the extent required by JPL, in connection with providing JPL Laboratory Services to perform solar cell and solar module manufacturing process steps, and testing as directed by JPL.

Status:

Contractor has performed satisfactorily. An add-on to this contract is now being considered. Original contract extended at no additional cost to JPL at JPL's request.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Automated Solar Panel Assembly Line
CONTRACT NUMBER: 955278

CONTRACTOR (NAME AND ADDRESS): ARCO Solar, Inc. 20554 Plummer St. Chatsworth, CA 91311 **TELEPHONE:** (213) 341- 9050 **PRINCIPAL INVESTIGATOR:** H. Somberg	**DIRECTING ORGANIZATION AND ADDRESS:** Jet Propulsion Laboratory Low-Cost Solar Array Project (502-422) 4800 Oak Grove Dr. Pasadena, CA 91109 **TELEPHONE:** (213) 577-9563 **PROJECT ENGINEER:** J. Behm
CURRENT CONTRACT PERIOD: **FROM:** 01/79 **TO:** 11/80	**CONTRACT FUNDING:** **SOURCE:** FY 79 $ 383,000 DOE FY 80 $ 90,275 DOE FY ___ $ ___ ___ FY ___ $ ___ ___ FY ___ $ ___ ___
PROBABLE PROJECT COMPLETION DATE: 4/81	
AREA/TASK: Production Process & Equipment	

SUMMARY:

Design, fabricate, develop and demonstrate an automated solar module assembly production line. The objective is to significantly reduce the price of current commercial flat plate photovoltaic modules available in the market place.

Status:

This contract is nearing completion; the final verification run remains to be completed along with high rate SAMICS cost projections and final report completion. The Contractor is continuing to do final design modifications and equipment adjustments to the automated soldering machine. The automated laminating system has been working well for some months and approximately 20,000 laminates (1 ft. X 4 ft.) have been successfully processed as part of ARCO Solar's on-going production line.

Remaining milestone target dates are:
1) Complete automation line verification demonstration (288 modules total) 1/9/81.
2) Deliver demo modules to JPL (56) 1/16/81.
3) Deliver SAMICS Analysis Report 2/9/81.
4) Deliver Final Draft Report 2/9/81.
5) Final Report Distribution 4/9/81.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design, Fabricate, Test, Quality of Block IV Solar Cell Modules

CONTRACT NUMBER: 955402

CONTRACTOR (NAME AND ADDRESS):

ARCO Solar
20554 Plummer
Chatsworth, CA 91311

TELEPHONE: (213) 341-9050

PRINCIPAL INVESTIGATOR: W. Bottenberg

DIRECTING ORGANIZATION AND ADDRESS:

Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9214

PROJECT ENGINEER: D. Runkle

CURRENT CONTRACT PERIOD:

FROM: 7/79 **TO:** 2/80

PROBABLE PROJECT COMPLETION DATE: 2/80

AREA/TASK: Module Production

CONTRACT FUNDING:

FY	$	SOURCE:
79	280,000	DOE
80	-0-	DOE

SUMMARY:

Design, fabricate, test, qualify, and deliver intermediate-load pre-productio solar cell modules and residential-load pre-production solar cell modules. Prepare a standardized price estimate with supporting analyses and input data for the approved module design for each of the two types of modules, using the Solar Array Manufacturing Industry Costing Standards (SAMICS) and the Solar Array Manufacturing Industry Simulation (SAMIS) computer program.

Status:

ARCO has provided intermediate load modules for testing which to date have not passed the hi-pot qualification test. As with Motorola this problem is receiving considerable attention. Arco has delivered no residential modules to JPL under this contract.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Evaluation of Silicon Production Suitable for Solar Cells
CONTRACT NUMBER: 954339

CONTRACTOR (NAME AND ADDRESS):
Battelle Memorial Institute
Columbus Laboratories
505 King Street
Columbus, OH 43201
TELEPHONE: (614) 424-7460
PRINCIPAL INVESTIGATOR: M. F. Browning

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109
TELEPHONE: (213) 354-6872
PROJECT ENGINEER: H. Levin

CURRENT CONTRACT PERIOD:
FROM: 10/75 **TO:** 11/80

PROBABLE PROJECT COMPLETION DATE: 11/80

AREA/TASK: Silicon Material

CONTRACT FUNDING:

		SOURCE:
FY 75	$ 85,000	DOE
FY 76	$ 194,999	DOE
FY 77	$ 493,758	DOE
FY 78	$ 430,000	DOE
FY 79	$ 632,000	DOE
80	818,000	DOE

SUMMARY:

Evaluate the prospect for low-cost solar silicon production by zinc reduction of silicon tetrachloride.

Status:

Operation of process development unit (PDU was scheduled to start October 1, 1979. Installation and start-up of PDU was not completed until February, 1980. During contract work period, extending through September, 1980, PDU had not been made fully operational. Failures were principally due to design problems.

September, 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Development of an All Metal Thick Film Cost Effective Metallization System for Solar Cells

CONTRACT NUMBER: 954688

CONTRACTOR (NAME AND ADDRESS):
Bernd Ross Associates
2154 Blackmore Court
San Diego, CA 92109

TELEPHONE: (714) 274-1391
PRINCIPAL INVESTIGATOR: Dr. Bernd Ross

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9255
PROJECT ENGINEER: B. Gallagher

CURRENT CONTRACT PERIOD:
FROM: 05/80 **TO:** 05/81

PROBABLE PROJECT COMPLETION DATE: 05/81

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
80	113,716	DOE

SUMMARY:

Perform expert analyses and critical evaluation of an economical improved thick film solar cell contact for high volume production of Low-Cost Silicon Solar Arra Modules.

Status:

All metal copper based back contacts have been sucessfully formulated, (85% copper, 5% lead, 5% silver fluoride and 5% silicon-aluminum eutedic) and have produced solar cells with efficiencies greater than 13%. Reproducibility problems have arisen in duplicating these results with recently forumulated inks. Neither the rheology of the green pastes nor their fired metallurgical properties were similar to the previously manufactured pastes. This is presently under investigation but should not impact the scheduled completion of the milestones.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Feasibility Study of Solar Dome Encapsulation of Photovoltaic Arrays

CONTRACT NUMBER: 954833

CONTRACTOR (NAME AND ADDRESS):
The Boeing Company
P. O. Box 3707
Seattle, WA 98124

TELEPHONE: (206) 575-5739

PRINCIPAL INVESTIGATOR: D. Zimmerman

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 354-3546

PROJECT ENGINEER: R. Weaver

CURRENT CONTRACT PERIOD:
FROM: 8/77 **TO:** 9/80

PROBABLE PROJECT COMPLETION DATE: 9/80

AREA/TASK: Engineering

CONTRACT FUNDING:

FY	$	SOURCE:
77	97,919	DOE
78	115,301	DOE
79	20,000	DOE
80	81,990	DOE

SUMMARY:

Phase I (FY 77)

Define and assess the potential technical and economic benefits obtained when solar photovoltaic arrays are protected by the air-supported structures. Completed and reported in DOE/JPL 954833 -78/1.

Phase II (FY 78-79)

Analytically determine wind loads on PV arrays both in fields of arrays and individually. Results reported in DOE/JPL 954833-79/2.

Phase III (FY 80)

Conduct wind tunnel tests to determine wind loads on arrays for design purposes. Report in progress.

Phase IV (FY 81)

Determine the structural dynamics of various support structures and, using the wind tunnel data from Phase III, determine the dynamic response of the structures. Work in Progress.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Operation and Maintenance Cost Data for Residential Photovoltaic Modules/Panels

CONTRACT NUMBER: 955614

CONTRACTOR (NAME AND ADDRESS):
Burt Hill Kosar Rittelmann Associates
400 Morgan Center
Butler, PA 16001

TELEPHONE: (412) 285-4761

PRINCIPAL INVESTIGATOR: R. Rittelmann

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 577-9111

PROJECT ENGINEER: R. Sugimura

CURRENT CONTRACT PERIOD:

FROM: 10/79 **TO:** 02/80

PROBABLE PROJECT COMPLETION DATE: 10/80

AREA/TASK: Engineering

CONTRACT FUNDING:

FY	$	SOURCE:
80	20,000	DOE

SUMMARY:

Produce a report covering Cost Data for the Operation and Maintenance of Photovoltaic Modules for Residential Applications. This report shall reflect projected 1986 Photovoltaic Module Technology and current building codes and construction practices.

Status:

The final report, JPL No. 9950-408, has been issued. The contract is in the final phase of closeout.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Commercial/Industrial Photovoltaic Modules Requirements Study
CONTRACT NUMBER: 955698

CONTRACTOR (NAME AND ADDRESS):
Burt Hill Kosar Rittelmann
400 Morgan Center
Butler, PA 16001

TELEPHONE: (412) 285-4761
PRINCIPAL INVESTIGATOR: J. Oster

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 577-9118
PROJECT ENGINEER: R. Sugimura

CURRENT CONTRACT PERIOD:
FROM: 04/80 TO: 03/81

PROBABLE PROJECT COMPLETION DATE: 03/81

AREA/TASK: Engineering

CONTRACT FUNDING:

FY	$	SOURCE:
80	115,354	DOE

SUMMARY:

Conduct a study to identify the design requirements for photovoltaic modules and arrays applicable to commercial/industrial installations, and provide a final report. The work shall reflect projected 1986 photovoltaic module technology and current building codes and construction proactices.

Status:

The work is proceeding on schedule. Current activities focus on development of electrical, structural, and mechanical requirements.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Exploratory Study of Product Safety and Product Liability Considerations for Photovoltaic Module/Array Devices

CONTRACT NUMBER: 955846

CONTRACTOR (NAME AND ADDRESS):
Carnegie-Mellon University
Department of Mechanical Engineering
Schenley Park
Pittsburgh, PA 15213

TELEPHONE:

PRINCIPAL INVESTIGATOR: A. Weinstein/D. Meeker

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 577-9580

PROJECT ENGINEER: E. Royal

CURRENT CONTRACT PERIOD:

FROM: 08/80 **TO:** 02/81

PROBABLE PROJECT COMPLETION DATE: 02/81

AREA/TASK: Engineering

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 14,423	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

Conduct an exploratory study and provide explicit considerations and recommendations relative to product safety on future solar photovoltaic module/array devide designs. The study is to be confined to flat-plate photovoltaic modules.

Status:

Study in progress/on schedule. Draft Final Report due in January,1981. That report will be released approximately one month later in February, 1981.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: System Study - Basic Aging and Diffusion

CONTRACT NUMBER: 954738

CONTRACTOR (NAME AND ADDRESS):
Case Western Reserve University
2040 Adelbert Road
Cleveland, OH 44106

TELEPHONE: (216) 368-4175

PRINCIPAL INVESTIGATOR: Charles Rogers

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 354-3465

PROJECT ENGINEER: R. Holtze

CURRENT CONTRACT PERIOD:
FROM: 03/77 **TO:** 12/81

PROBABLE PROJECT COMPLETION DATE: 12/81

AREA/TASK:
Encapsulation

CONTRACT FUNDING:		SOURCE:
FY 80	$ 55,000	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

Determine the dependence of sorption, diffusion, and permeability of water and environmental gases on the nature and extent of photo-degradation of polymers.

Status:

The present work is aimed toward establishing the modes of degradation of poly (n-butylacrylate) (PNBA) and establishing the relationships between selected chemical changes and physical properties. The objective of these current studies is to predict long-term physical changes from the short-term testing and measurements of chemical changes.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Investigation of Reliability and Accelerated Stress Factors on Terrestrial Solar Cells

CONTRACT NUMBER: 954929

CONTRACTOR (NAME AND ADDRESS):
Clemson University
College of Engineering
Clemson, SC 28631

TELEPHONE: (803) 656-3371

PRINCIPAL INVESTIGATOR: J. Lathrop

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 577- 9580

PROJECT ENGINEER: E. Royal

CURRENT CONTRACT PERIOD:
FROM: 12/77 **TO:** 10/81

PROBABLE PROJECT COMPLETION DATE: 10/81

AREA/TASK: Engineering

CONTRACT FUNDING:

FY	$	SOURCE:
78	123,649	DOE
79	110,534	DOE
80	81,308	DOE

SUMMARY:

Perform investigations of factors involved in the reliability of terrestrial solar cells and develop a specification for accelerated stress testing of solar cells.

Status:

A. Three new cell types have been added to the test program. The cell types added utilized new, potentially low cost metallization, ie. copper-vs.-silver, etc. This is part of a cooperative effort between LSA Engineering Area and and the PP & E Area.

B. Two (2) documents are scheduled for approval and issuance by January, 1981. These documents are: (1) Draft Final Report - Third Annual, and (2) Proceedings of Workshop on Determining Terrestrial Solar Cell Reliability - a workshop organized by Clemson in fulfillment of a requirement to this contract. The proceedings will be issued as a LSA document.

September, 1980

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Characterization of Structural, Electrical and Chemical Properties of Silicon

CONTRACT NUMBER: 954852

CONTRACTOR (NAME AND ADDRESS):
Cornell University
123 Day Hall, P. O. Box DH
Ithaca, NY 14853

TELEPHONE: (607) 256-4140

PRINCIPAL INVESTIGATOR: D. Ast

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-3068

PROJECT ENGINEER: L. Cheng

CURRENT CONTRACT PERIOD:

FROM: 03/78 **TO:** 11/81

PROBABLE PROJECT COMPLETION DATE: 11/81

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE:
78	90,000	DOE
80	-0-	DOE

SUMMARY:

Perform basic research leading to the understanding of structural, electrical and chemical nature of silicon sheet material. The efforts are to be directed towards correlating the structural, electrical and chemical properties of silicon sheet material leading to the better understanding of their potential to produce high efficiency solar cells.

Status:

Silicon sheet material was analyzed by optical microscopy and etching, electron beam induced current microscopy, conventional transmission electron microscopy, and high voltage transmission electron microscopy at 1.2MeV. The accomplishments made so far include the following new observations:

a) Web material

   (1) The central twinning region may be a microtwin or twins.
   (2) Dislocations with burgers vectors of the <211> type accommodate small tilt components between the twin planes.
   (3) Hexagonal partial dislocations arrays accommodate small twist components between the twin planes.

b) EFG material

   (1) The electrical activity of twin boundaries exhibiting dotted EBIC contract is associated with the presence of partial dislocations in the boundary.

   (2) A significant fraction of the straight twin boundaries present are secondary twins of the (111)-(115) type. These secondary twins contain a high density of dislocations and are strongly electrically active.

Presently, investigations on HEM are in progress. In addition, studies of the effect of cell fabrication processes on defect structure and their electrical activities are planned to be performed.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: HEM/Fast Process

CONTRACT NUMBER: 954373

CONTRACTOR (NAME AND ADDRESS):
Crystal Systems, Inc.
35 Congress Street
Salem, MA 01970

TELEPHONE: (617) 745-0088

PRINCIPAL INVESTIGATOR: F. Schmid

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-6546

PROJECT ENGINEER: K. Dumas

CURRENT CONTRACT PERIOD:
FROM: 11/75 TO: 12/80

PROBABLE PROJECT COMPLETION DATE: 3/81

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

		SOURCE:
FY 76	$ 208,393	DOE
FY 77	$ 427,408	DOE
FY 78	$ 399,832	DOE
FY 79	$ 373,855	DOE
FY 80	$ 687,345	DOE
81	100,000	DOE

SUMMARY:

Develop methods of producing large areas of silicon sheet material by the heat exchange method-ingot casting/fast slicing process suitable for use as solar cells. The methods to be developed are to be directed toward minimum cost processing of silicon into sheet configurations of a quality suitable for producing solar cells with a terrestrial efficiency greater than 15% (AM1) and having potential to be scaled for large quantity production.

Status:

HEM Program

Technical difficulties occurred when CSI attempted to grow large ingots. The growth problems combined with updated economic analyses caused JPL to redirect the program. New goals include growing smaller ingots (dimensions 30 cm X 30 cm X 15cm) in longer cycle times (<56 hours). Greater emphasis will be placed on optimizing the process for the purpose of impounding the material quality. The program will be extended by three months in order to meet the new goals.

FAST Program

A new 750 wire bladehead was installed four months behind schedule. The usual debugging problems have occurred which are still not completely under control. Also, the necessary improvement of the wires has not happened. Consequently, none of the milestones for this contract have been completed. Judging from the progress made so far this year, CSI will have difficulty meeting their slicing goals by the end of the current contract.

September 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Study of Effects of Impurities in Silicon Materials
CONTRACT NUMBER: 954685

CONTRACTOR (NAME AND ADDRESS):
C. T. Sah Associates
403 Pond Ridge Lane
Urbana, IL 61801

TELEPHONE: (217) 328-1925
PRINCIPAL INVESTIGATOR: C. T. Sah

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propuslion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109
TELEPHONE: (213) 577-9092
PROJECT ENGINEER: A. Yamakawa

CURRENT CONTRACT PERIOD:
FROM: 02/77 **TO:** 10/81

PROBABLE PROJECT COMPLETION DATE: 10/81

AREA/TASK: Silicon Material

CONTRACT FUNDING:

FY	$	SOURCE:
77	36,158	DOE
78	104,000	DOE
79	59,000	DOE
80	49,991	DOE

SUMMARY:

Conduct a program of study on the effects of impurities on the properties of silicon material and performance of silicon solar cells.

Status:

The effects of zinc on silicon solar cells was investigated, this element being a major residue impurity in silicon produced by the Battelle process. Computed values for the efficiency of these cells indicate that for a 17% AMI efficiency (no surface reflection), the zinc concentration must be less than about 4 x 10" Zn/cm^3 in an $n^+/p/p^+$ cell and 7 X 10" Zn/cm^3 in a $P^+/n/n^+$ cell for 5 X 10" atoms $/cm^3$ base doping and 250 μm cell thickness.

The effects of cell thickness on the efficiency of back-surface-field solar cells with zinc impurity were also studied.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Low Angle Silicon Sheet Growth Development
CONTRACT NUMBER: 955378

CONTRACTOR (NAME AND ADDRESS):
Energy Materials Corporation
Ayer Road
Harvard, MA 01451

TELEPHONE: (617) 456-8797
PRINCIPAL INVESTIGATOR: David Jewett

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-7200
PROJECT ENGINEER: A. Morrison

CURRENT CONTRACT PERIOD:
FROM: 05/79 **TO:** 09/80

PROBABLE PROJECT COMPLETION DATE: 09/80

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE:
79	30,006	DOE
80	14,643	DOE

SUMMARY:

The contractor to experimentally test the growth stability features of the proposed low-angle sheet growth to establish basic feasibility by experimentally testing the key features, which are: Crystal width control, leading growth edge control, and scraper function in raised meniscus growth area.

Status:

Process feasibility was demonstrated under the subject contracts.

Comment:

Support of the low-angle sheet growth technology at EMC has been transferred to SERI - more R&D required.

September 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Gaseous Melt Replenishment System

CONTRACT NUMBER: 955269

CONTRACTOR (NAME AND ADDRESS): Energy Materials Corp. Ayer Road Harvard, MA 01451	**DIRECTING ORGANIZATION AND ADDRESS:** Jet Propulsion Laboratory Low-Cost Solar Array Project (502-422) 4800 Oak Grove Drive Pasadena, CA 91109
TELEPHONE: (617) 456-8707	**TELEPHONE:** (213) 354-7215
PRINCIPAL INVESTIGATOR: David Jewett	**PROJECT ENGINEER:** P. Seshan

CURRENT CONTRACT PERIOD:
FROM: 04/79 **TO:** 10/80

PROBABLE PROJECT COMPLETION DATE: 10/80

AREA/TASK: Silicon Material

CONTRACT FUNDING:

FY	$	SOURCE:
79	240,000	DOE
80	89,002	DOE

SUMMARY:

The contractor shall develop and demonstrate a silicon melt replenishment system for continuous Czochralski crystal growth. The melt replenishment system shall consist of (i) a novel reactor for production and melting of silicon (at a rate of 0.5 kg/hr) through hydrogen reduction of $SiHCl_3$ (at a conversion efficiency of 18 mole percent), and (ii) a delivery system to transfer molten silicon to a Czochralski crystal puller.

Status:

The reactor was constructed and operated. The demonstrated production rate was only 0.25 kg/hr of silicon. However, conversion efficiencies greater than 18 mole percent were achieved.

The contract ended on October 17, 1980. Since the effort will not be extended the program objective of a durable, continuously operating melt replenishment system was not realized.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Integrated Residential Photovoltaic Array Development **CONTRACT NUMBER:** 955894	
CONTRACTOR (NAME AND ADDRESS): General Electric Corporation Valley Forge Space Center King of Prussia Park P. O. Box 8661, Philadelphia, PA 19101 **TELEPHONE:** (215) 962-5839 **PRINCIPAL INVESTIGATOR:** N. Shepard	**DIRECTING ORGANIZATION AND ADDRESS:** Jet Propulsion Laboratory Low-Cost Solar Array Project 502-422 4800 Oak Grove Drive Pasadena, CA 91109 **TELEPHONE:** (213) 577-9118 **PROJECT ENGINEER:**
CURRENT CONTRACT PERIOD: **FROM:** 10/24/80 **TO:** 11/81	**CONTRACT FUNDING:** / **SOURCE:** FY 80 $ 100,000 DOE FY ___ $ ___ ___ FY ___ $ ___ ___
PROBABLE PROJECT COMPLETION DATE: 11/81	FY ___ $ ___ ___
AREA/TASK: Engineering	FY ___ $ ___ ___

SUMMARY:

The Contractor shall develop an Integrated Residential Photovoltaic Array Design Package (PV-only), complete with detailed drawings to permit manufacture, fabrication and installation by a third party, and provide a full-scale, representative section of a residential photovoltaic array, complete with electrical and mechanical interconnects and support hardware in accordance with the goals set forth in this Contract.

Status:

New Contract.

September 1980

BEST DOCUMENT AVAILABLE

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Development of a Polysilicon Process
CONTRACT NUMBER: 955533

CONTRACTOR (NAME AND ADDRESS):
Hemlock Semiconductor Corporation
12334 Geddes Road
Hemlock, MI 48626

TELEPHONE: (517) 624-5201
PRINCIPAL INVESTIGATOR: J. R. McCormick

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-4883
PROJECT ENGINEER: A. Briglio, Jr.

CURRENT CONTRACT PERIOD:
FROM: 10/79 **TO:** 1/81

PROBABLE PROJECT COMPLETION DATE: 1/81

AREA/TASK: Silicon Material

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 150,000	DOE
FY 80	$ 577,000	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

The contractor shall conduct detailed studies, testing and associated efforts to develop a low-cost process for producing polysilicon approaching semiconductor-grade quality by chemical vapor deposition from dichlorosilane and/or mixtures of dichlorosilane and trichlorosilane.

Status:

In tests with an experimental reactor, the deposition rate of silicon (Si) from dichlorosilane (DCS) was doubled compared to that obtained using trichlorosilane (TCS), this increase being more than the amount needed to attain the contract goals. The conversion efficiency was increased by a factor of 3 over that with TCS, and the power consumption was substantially reduced.

The catalytic conversion of TCS to DCS was investigated in a laboratory-scale apparatus, and a process development unit (PDU) was designed to study this conversion and larger scale and to supply the DCS needed for tests of larger reactors. Construction of the PDV has been delayed because safety-related tests on DCS indicated that the hazards associated with using this substance are greater than the literature indicates. However, a suitable site for the PDV has been selected and the PDV design modified to factor in the results of the safety tests.

A preliminary economic analysis for a 1000-MT Si/yr production plant was performed, indicating a product price of about $20/kg (1980 dollars, 20$ ROI).

September, 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Dip Coating Process
CONTRACT NUMBER: 954356

CONTRACTOR (NAME AND ADDRESS):
Honeywell, Inc.
10701 Lyndale Ave.
Bloomington, MN 55420

TELEPHONE: (612) 887-4383
PRINCIPAL INVESTIGATOR: D. Zook

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 354-5782
PROJECT ENGINEER: T. Daud

CURRENT CONTRACT PERIOD:
FROM: 10/75 **TO:** 12/80

PROBABLE PROJECT COMPLETION DATE: 12/80

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE
76	193,229	DOE
77	480,555	DOE
78	400,000	DOE
79	478,112	DOE
80	569,999	DOE

SUMMARY:

Determine the feasibility of silicon films on ceramic (SOC) as a means of producing large areas of silicon sheet for use as photovoltaics in terrestrial power generating systems.

Status:

Continuous coating of silicon on non-slotted mullite-substrates was demonstrated on SCIMII for 10 cm. wide substrates at coating speeds of up to 30 cm/min. (Project goal 12.5 cmx 15 cm/min). The silicon coatings are fairly uniform but very thin (less than 10 μm against a project goal of 100 μm).

Coating of slotted substrates has been taken up now. A few coating at low speeds (3-5 cm/min) has resulted in thicker (>50 μm) silicon and the same will be processed for solar cells.

Dip coating process has also been operational for cell fabrication effort but the efficienes of AR coated cells have continued to be around 10% (against an LSA goal of 11% encapsulated cell efficiency).

the SOC program work at JPL for the LSA Project will be transferred to SERI at the end of the current (12/30). This is because of budget limitations and schedule slippages.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Technical Support in Reliability Engineering of Photovoltaic Modules

CONTRACT NUMBER: 955720

CONTRACTOR (NAME AND ADDRESS):

IIT Research Institute
10 West 35th Street
Chicago, IL 60616

TELEPHONE: (312) 567-4511

PRINCIPAL INVESTIGATOR: P. Mihalkanin

DIRECTING ORGANIZATION AND ADDRESS:

Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9580

PROJECT ENGINEER: E. Royal

CURRENT CONTRACT PERIOD:

FROM: 03/80 **TO:** 01/81

PROBABLE PROJECT COMPLETION DATE: 01/81

AREA/TASK: Engineering

CONTRACT FUNDING:

FY	$	SOURCE:
80	73,747	DOE

SUMMARY:

Conduct a preliminary reliability analysis study of field failure data accumulated on flat-plate photovoltaic array/module designs and critique present LSA Project reliability practices and Data Analysis procedures. With this as a data base for reference, IIT RI will participate with LSA Engineering Area in development of various elements of what will later be a Reliability Engineering Design Guide book. IIT RI will perform in a support role. Actual release of any reliability engineering design guidelines will be by the LSA Engineering Area.

Status:

Draft of Quarterly Report received and reviewed. This Quarterly Report is to be issued to LSA and Photovoltaic community in November, 1980.

September 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Deposit of Anti-Reflective Coating by Ion Plating

CONTRACT NUMBER: 955506

CONTRACTOR (NAME AND ADDRESS):
Illinois Tool Works
1427 Holmes Rd.
Elgin, IL 60120

TELEPHONE: (312) 741-6800

PRINCIPAL INVESTIGATOR: S. Stefan

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 354-3188

PROJECT ENGINEER: E. Cuddihy

CURRENT CONTRACT PERIOD:

FROM: 12/79 **TO:** 08/81

PROBABLE PROJECT COMPLETION DATE: 08/81

AREA/TASK: Encapsulation

CONTRACT FUNDING:

FY	$	SOURCE
79	60,000	DOE
80	60,000	DOE

SUMMARY:

Demonstration of capability to deposit Anti-Reflective (AR) coatings by ion-plating.

Status:

The deposition of AR coatings on both glass and solar cells has been demonstrated. An investigation of the feasibility of using ion-plating as a production fabrication technique to sequentially deposit low-cost corrosion resistant metallization systems followed by an ion-plated AR coating has encountered problems in achieving satisfactory ohmic contact on silicon cells. If this cannot be resolved during the first half of FY81 the ion-plating effort will be redirected.

September, 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Development of Advanced Methods for Continuous Cz Growth

CONTRACT NUMBER: 954888

CONTRACTOR (NAME AND ADDRESS):
Kayex Corporation
Hamco Division
1000 Milstead Way
Rochester, NY 14624
TELEPHONE: (716) 235-2524
PRINCIPAL INVESTIGATOR: R. Lane

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 354-7200
PROJECT ENGINEER: A. Morrison

CURRENT CONTRACT PERIOD:
FROM: 12/77 **TO:** 09/81

PROBABLE PROJECT COMPLETION DATE: 9/81

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE:
78	270,000	DOE
79	246,892	DOE
80	197,379	DOE

SUMMARY:

Develop methods of demonstrating continuous Czochralski growth. Continuous growth is defined as a throughput of silicon that produces 100 Kg of silicon single crystal(s) material of ten cm in diameter or greater, utilizing one common silicon container material (one crucible).

Status:

All of the goals of this contract were achieved with the exception of throughput (2.1 kg) hr vs. 2.5 kg/hr. goal). A new CPFF completion type contract with TR demonstration (150 kg of ingots, 15 cm in diameter, from a single crucible, capable of achieving 15% average AM1 photovoltaic conversion efficiency, 2.5kg/hr throughput rate) was signed October, 1980.

September, 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Low Cost Czochralski Crystal Growing Technology
CONTRACT NUMBER: 955270

CONTRACTOR (NAME AND ADDRESS):
Kayex Corporation
1000 Milstead Way
Rochester, NY 14624

TELEPHONE: (716) 235-2524
PRINCIPAL INVESTIGATOR: R. Lane

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 354-7200
PROJECT ENGINEER: A. Morrison

CURRENT CONTRACT PERIOD:
FROM: 03/79 **TO:** 09/80

PROBABLE PROJECT COMPLETION DATE: 09/80

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE
79	250,000	DOE
80	199,990	DOE

SUMMARY:

Develop and demonstrate continuous Czochralski growth technology. Continuous Czochralski growth is defined as a throughput of greater than 150 Kg of silicon crystals material of fifteen cm in diameter, utilizing one common crucible.

Status:

Three areas of development were emphasized under the subject Near-term Cost Reduction contract. They were: Accelerated feedstock melt down and crystal growth by introduction of a water-cooled r-f coil into the growth system, r-f melting and melt levitation recharging of the system, and growth process automation using a micro-processor. Each of these was addressed and partially accomplished. Hardware and process improvements achieved are being incorporated into the design for the Experimental Sheet Growth Unit, the prototype TR Advanced Cz growth system.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Advanced CZ Growth Process
CONTRACT NUMBER: 955733

CONTRACTOR (NAME AND ADDRESS):
Kayex Corporation
1000 Millstead Way
Rochester, NY 14624

TELEPHONE:
PRINCIPAL INVESTIGATOR:

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109
TELEPHONE: (213) 354-7200
PROJECT ENGINEER: A. Morrison

CURRENT CONTRACT PERIOD:
FROM: 9/26/80 **TO:** 12/81

PROBABLE PROJECT COMPLETION DATE: 12/81

AREA/TASK:
Large Area Silicon Sheet

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 153,440	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The Contractor shall provide properly qualified personnel within appropriate scientific, engineering and technical classification to develop a continuous Czochralski growth process capable of producing silicon suitable for use as low-cost solar cells. The cost goal is less than $700 (1980$) per peak kilowatt by 1986. The goals of this program are:

- Continuous growth of 150kg or more of multiple ingots, each of approximately 30kg in weight, from one common crucib-e with melt-replenishment.
- Resistivity of 1 to 3 ohmOcm, p-type, in all crystals.
- Dislocation density below 10^4 per cm^2.
- Diameter of 15cm for each ingot.
- Growth throughput greater than 2.5kg per hour of machine operation.
- Orientation: (100)
- After growth yield of greater than 90%.
- Prototype equipment suitable for high volume silicon production transferable directly to industry.

Status:

New Contract.

BEST DOCUMENT AVAILABLE

September 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Process Feasibility Study
CONTRACT NUMBER: 954343

CONTRACTOR (NAME AND ADDRESS):
Lamar University
P. O. Box 10053
Beaumont, TX 77710
TELEPHONE: (713) 838-8310
PRINCIPAL INVESTIGATOR: C. Yaws

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91103
TELEPHONE: (213) 354-7648
PROJECT ENGINEER: R. Lutwack

CURRENT CONTRACT PERIOD:
FROM: 10/75 **TO:** 2/81

PROBABLE PROJECT COMPLETION DATE: 2/81

AREA/TASK: Silicon Material

CONTRACT FUNDING:

FY	$	SOURCE:
76	99,962	DOE
77	205,480	DOE
78	70,086	DOE
79	192,012	DOE
80	(37,540)	DOE
81	40,000	DOE

SUMMARY:

Contractor shall perform a program of investigations and analyses of processes for the low-cost, high-volume production of silicon suitable for solar cells. The objective is to evaluate the commercial practicality of the processes. Perform analyses which shall lead to physical and chemical descriptions of the process systems and to evaluations relative to the objective. Perform theoretical and experimental studies and analyses which shall determine the kinetic and yield properties of the processes. Perform economic analyses of the processes.

Status:

Preliminary process design of the Battelle Columbus Laboratories process for making silicon was conducted for the case of one deposition reactor and two electrolysis cells. For a production plant of 1000-MT/yr capacity, the product price is $17.19/kg (1980 dollars, 20% ROI). Analysis of the Hemlock process for silicon production was started. Changes in the process flow sheet were introduced to increase yield of dichlorosilane, help insure product purity, and reduce the amount of substance in the reactor feed material that might form silicon dust by fine particle nucleation.

Analyses were continued on property data for materials important in the production of silicon. Data were presented on the physical, thermochemical, and transport properties of silicon itself.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Evaluation of Laser Annealing of Solar Cells

CONTRACT NUMBER: 955696

CONTRACTOR (NAME AND ADDRESS):
Lockheed Missiles and Space Company, Inc.
1111 Lockheed Way
Sunnyvale, CA 94086

TELEPHONE: (408) 743-0466

PRINCIPAL INVESTIGATOR: J. Katzeff

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9374

PROJECT ENGINEER: D. Burger

CURRENT CONTRACT PERIOD:
FROM: 03/80 **TO:** 03/81

PROBABLE PROJECT COMPLETION DATE: 03/81

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:		SOURCE:
FY 80	$ 100,000	DOE
FY 81	$ 33,000	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Evaluate laser annealing of silicon wafers in the manufacture of solar cells.

Status:

The second quarterly report on this contract has just been received. Results show cell efficienies equal to or higher than furnace anneal control cells for some combinations of ion implantation and laser annealing. Beam homogenization has been demonstrated and a higher efficiency alternative was examined but will not be pursued due to contract limitations. The next quarter should achieve beam parameter optimization, wafer fabrication and process verification. Most of the data necessary to specify the next generation of laser annealing equipment will also be available by January, 1981.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Investigation of the Hydrochlorination of Metallurgical-Grade Silicon

CONTRACT NUMBER: 955382

CONTRACTOR (NAME AND ADDRESS):
Massachusetts Institute of Technology
Office of Sponsored Programs
Cambridge, MA 02139

TELEPHONE: (617) 253-1858

PRINCIPAL INVESTIGATOR: J. Mui

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-7428

PROJECT ENGINEER: G. Hsu

CURRENT CONTRACT PERIOD:

FROM: 04/79 **TO:** 03/81

PROBABLE PROJECT COMPLETION DATE: 03/81

AREA/TASK: Silicon Material

CONTRACT FUNDING:

FY	$	SOURCE:
79	80,000	DOE
80	120,000	DOE

SUMMARY:

The Contractor shall provide data for the reaction for they hydrochlorination of metallurgical-grade silicon to form trichlorosilane for producing low-cost high-purity silane. The goal of this contract is to support the Union Carbide Silane-to Silicon Process in the LSA Silicon Material Task by donducting experimental and theoretical studies in the following areas:

(1) Reaction kinetics and role of the catalyst [illegible] the hydrochlorination of metallurgical grade silicon; and

(2) Optimization of operating condition for the hydrochlorination step.

Status:

This contract is progressing according to schedule. An improved reactor design which provides a significant cost reduction has been obtained. With the completion of the studies of reaction kinetics and of particle size effects, work has been started on impurity and mass life effects.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Analysis of Defects Structure in Silicon

CONTRACT NUMBER: 955676

CONTRACTOR (NAME AND ADDRESS):

Materials Research, Inc.
790 East 700 South
Centerville, Utah 84014

TELEPHONE: (801) 531-9600

PRINCIPAL INVESTIGATOR: Dr. R. Natesh

DIRECTING ORGANIZATION AND ADDRESS:

Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-5465

PROJECT ENGINEER: T. O'Donnell

CURRENT CONTRACT PERIOD:

FROM: 6/26/80 **TO:** 7/25/81

PROBABLE PROJECT COMPLETION DATE: 7/25/81

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 80,000	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The Contractor shall perform quantitative analysis, using quantitative microscopy equipment, of selected silicon samples supplied by JPL, as described in Exhibit 1 to this Contract entitled "Silicon Sample Types for Quantitative Analysis of Defects" dated May 15, 1980. The Contractor shall utilize methods of characterization for analysis of the structure of silicon developed under JPL Contract No. 954977, as applicable, and shall develop methods of characterization to characterize the structure of silicon crystals according to grain size, dislocation density, twin density and impurity precipitates, as necessary.

Status:

Procedures have been developed for accurate, reproducible and quantitative analysis of silicon sheet defect structure. A Quantimet (QTM-720) Image Analyzing System, incorporating a PDP 11/03 minicomputer with dual floppy disc drive, high speed printer, Field-Image Feature Interface (FIFI) Module and an automated X-Y specimen stage control has been and is being used in this development/evaluation program. A computer program for defect characterization of silicon was developed and submitted to JPL as a new technology item.

EFG, RTR and CAST ribbon material has been characterized. Present effort involves characterizing HEM ingot material, WEB ribbon and SOC sheet material. Future efforts will also involve depth profiling of dislocation density on as-sawn Cz wafers.

September, 1980

8

TITLE: Automation Equipment Development and Modification

CONTRACT NUMBER 955699

CONTRACTOR (NAME AND ADDRESS):
MB Associates
Ballinger Canyon Road
San Ramon, CA 94583

TELEPHONE: (415) 837-7201

PRINCIPAL INVESTIGATOR: Mr. J. Haggerty

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9324

PROJECT ENGINEER: P. Alexander

CURRENT CONTRACT PERIOD:

FROM: 7/1/80 **TO:** 8/81

PROBABLE PROJECT COMPLETION DATE: 8/81

AREA/TASK: Production Process and Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
80	100,000	DOE

SUMMARY:

The contractor shall develop, test and deliver automation equipment which, when used with a JPL-supplied Unimation Robot, shall be capable of interconnecting and emplacing solar cells in modular configuration, and encapsulating and assembling solar modules.

Status:

The contract is on schedule. A mock-up lamination station has been completed. Designs for the final configured lamination and encapsulation stations were generated in October, 1980.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Edge-Defined Film-Fed Growth for Silicon Growth Development
CONTRACT NUMBER: 954355

CONTRACTOR (NAME AND ADDRESS):
Mobil-Tyco Solar Energy Corporation
16 Hickory Drive
Waltham, MA 02156

TELEPHONE: (617) 890-0909
PRINCIPAL INVESTIGATOR: F. Wald

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-4583
PROJECT ENGINEER: R. Kachare

CURRENT CONTRACT PERIOD:
FROM: 10/75 **TO:** 12/80

PROBABLE PROJECT COMPLETION DATE: 12/80

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

		SOURCE:
FY 76	$ 259,353	DOE
FY 77	$ 895,000	DOE
FY 78	$ 910,423	DOE
FY 79	$ 777,010	DOE
FY 80	$ 767,996	DOE
81	139,000	DOE

SUMMARY:

Development of growth of silicon ribbon by the edge-defined film-fed growth (EFG) for low-cost large area photovoltaic for terrestrial applications.

Status:

Mobil-Tyco Solar Energy Corporation (MTSEC) has grown three ribbons each of 10 cm wide at an average growth rate of approximately 3.0 cm/min on two occasions with melt-replenishment approach for short periods of time (∿ 2-3 hours). The goal of making such growth runs at a growth rate of 4.cm/min for 8 hours has not been achieved. It is anticipated that this goal may be met around March, 1981. The program plan for Technical Readiness (TR 82) is currently under development which will include design fabrication and process testing.

September 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Phase 2 of the Array Automated Assembly Task

CONTRACT NUMBER: 954847

CONTRACTOR (NAME AND ADDRESS):
Motorola Inc.
5005 East McDowell Rd.
Phoenix, AZ 85008

TELEPHONE: (602) 244-5511

PRINCIPAL INVESTIGATOR: M. Coleman

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 354-4792

PROJECT ENGINEER: D. Fitzgerald

CURRENT CONTRACT PERIOD:
FROM: 09/77 **TO:** 11/80

PROBABLE PROJECT COMPLETION DATE: 11/80

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE
FY 77	$ 170,000	DOE
FY 78	$ 296,870	DOE
FY 79	$ 400,000	DOE
FY 80	$ 199,705	DOE
FY	$	

SUMMARY:

A process sequence shall be specified which, when automated, would have the potential of mass producing silicon solar cell array modules encapsulated for protection against the Earth environment. This sequence shall be critically analyzed for cost effectiveness, quality throughput and reproducibility of the product.

Status:

The last year of this contract has focused on the feasability and economics of several processes for solar cell production. Motorola has been able to eliminate the costly requirement of using palladium as an interface between the silicon and the metallization system. They have shown that nickel can be plated directly to the silicon by using either electrolytic or electroless techniques. They have also shown that copper is the most cost-effective metallization system and that nickel provides a suitable barrier against copper migration into the silicon. Motorola has demonstrated that plasma patterning of a silicon nitride layer on the silicon surface can make line widths as small as one mill (25μm) down to the bare silicon. The silicon nitride provides a mask for plating the metallization patterns onto the silicon and acts as an anti-reflective (AR) coating. This replaces the more costly photresist and to apply the AR coating. Motorola has shown that plasma etching is not a cost effective way of removing saw damage. Finally, this contractor has made solar cells using ion implantation without mass analysis.

The experimental phase of the contract has been completed. However, Motorola is still obligated to submit a corrected version of the final report (JPL has reviewed the first draft) and some other deliverables. The deliverables include samples of RTR sheet material that have been made into cells using the processes developed under this contract.

BEST DOCUMENT AVAILABLE

September, 1980

G. Nail

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Development of Advanced Methods for Continous Cz Growth

CONTRACT NUMBER: 954886

CONTRACTOR (NAME AND ADDRESS):
Siltec Corporation
3717 Haven Ave.
Menlo Park, CA 94025

TELEPHONE: (415) 365-8600

PRINCIPAL INVESTIGATOR: G. Fiegl

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-4583

PROJECT ENGINEER: R. Kachare

CURRENT CONTRACT PERIOD:

FROM: 12/77 **TO:** 08/80

PROBABLE PROJECT COMPLETION DATE: 08/80

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE:
78	339,000	DOE
79	225,580	DOE
80	334,370	DOE

SUMMARY:

Design and develop equipment and processes to demonstrate continuous growth of crystals by the Czochralski process suitable for processing into solar cells. Continuous is defined as the growth of at least 150 kg of silicon 150 mm in diameter from one growth container. The approach to meeting this goal is to develop a furnace with continuous liquid replenishment of the growth crucible.

Status:

Currently Siltec Corporation is in negotiations for a new development contract from JPL for the continuous liquid feed Czochralski growth. Siltec has produced 100 kg silicon ingots by using the liquid feed approach. However, Siltec has not yet met the goal of producing 150 kg silicon ingot from a single run. This milestone was supposed to be achieved by the end of August, 1980.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Establishment of a Production-Ready Manufacturing Process Utilizing Thin Silicon Substrates for Solar Cells

CONTRACT NUMBER: 955328

CONTRACTOR (NAME AND ADDRESS):
Motorola, Inc.
Semiconductor Group
5005 East McDowell Rd.
Phoenix, AZ 85008
TELEPHONE: (602) 244-5511
PRINCIPAL INVESTIGATOR: R. White

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 577-9324
PROJECT ENGINEER: P. Alexander

CURRENT CONTRACT PERIOD:
FROM: 01/79 **TO:** 11/80

PROBABLE PROJECT COMPLETION DATE: 11/80

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
79	260,000	DOE
80	82,351	DOE

SUMMARY:

Investigate, develop and characterize methods to establish a production-ready manufacturing process which utilizes thin silicon substrates for solar cells.

Status:

The contract is completed except for the final report. The draft final report is scheduled for completion by November 15, 1980.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Block IV Solar Cell Modules

CONTRACT NUMBER: 955406

CONTRACTOR (NAME AND ADDRESS):

Motorola, Inc.
Semiconductor Group
5005 E. McDowell Rd.
Phoenix, AZ 85008

TELEPHONE: (602) 244-5511

PRINCIPAL INVESTIGATOR: B. Larson

DIRECTING ORGANIZATION AND ADDRESS:

Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9214

PROJECT ENGINEER: D. Runkle

CURRENT CONTRACT PERIOD:

FROM: 5/79 **TO:** 3/80

PROBABLE PROJECT COMPLETION DATE: 12/80

AREA/TASK: Module Production

CONTRACT FUNDING:

FY	$	SOURCE:
79	107,500	DOE
80	-0-	DOE

SUMMARY:

Design, fabricate, test, qualify, deliver pre-production solar cell modules which comply with requirements of JPL Document 5101-16 Rev. A, entitled, "Block IV Solar Cell Module Design and Test Specification for Intermediate Load Center Applications." Prepare also a standardized price estimate for 10, 100, and 1000 kW of modules delivered in 1980.

Status:

Modules have been delivered, however a problem involving failure during high-pot testing has kept the module from being qualified. At the present time this particular problem has been solved, but it has raised a question regarding grounding and safety that is presently under consideration.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Fabricate Block IV Modules

CONTRACT NUMBER: 955410

CONTRACTOR (NAME AND ADDRESS):
Sensor Technology, Inc. (Photowatt)
2414 W. 145h Street
Tempe, AZ 95281

TELEPHONE: (602) 968-3618

PRINCIPAL INVESTIGATOR: M. Keeling

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9214

PROJECT ENGINEER: D. Runkle

CURRENT CONTRACT PERIOD:

FROM: 4/24/79 TO: 9/15/80

PROBABLE PROJECT COMPLETION DATE: 3/81

AREA/TASK: Module Production

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 124,599	DOE
FY 80	$ -0-	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Design, fabricate, test, qualify, deliver pre-production solar cell modules which comply with requirements of JPL Document 5101-16 Rev. A, entitled, "Block IV Solar Cell Modules Design and Test Specifications for Intermediate Load Center Applications." Prepare also a standardized price estimate for 10, 100, and 1000 kW of modules delivered in 1980.

Status:

Sensor Technology has designed two different modules in the course of this contract. The design of the first module was abandoned as being too expensive to fabricate in a competetive world. The second has yet to be subjected to qualification testing. This latter event should occur late in November 1980. The progress at Sensor Tech has been hampered by a move from Chatsworth, CA to Phoenix, AZ, which followed a corporate metamorphosis from Sensor Technology, Inc., to Photowatt International.

September, 1980

TITLE: Anti-Reflective Coatings on Large Area Glass Sheets

CONTRACT NUMBER: 955339

CONTRACTOR (NAME AND ADDRESS):
Motorola, Inc.
Semiconductor Group
5005 East McDowell Rd.
Phoenix, AZ 85008

TELEPHONE: (602) 244-511

PRINCIPAL INVESTIGATOR: R. White

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
Pasadena, CA 91109

TELEPHONE: (213) 354-4482

PROJECT ENGINEER: F. Bouquet

CURRENT CONTRACT PERIOD:

FROM: 01/79 **TO:** 04/80

PROBABLE PROJECT COMPLETION DATE: 08/80

AREA/TASK: Encapsulation

CONTRACT FUNDING:

FY	$	SOURCE
79	170,622	DOE
80	-0-	DOE

SUMMARY:

Conduct detailed studies and testing of anti-reflective (AR) coatings for soda-lime glass resulting in perfected low-cost processes for producing a long-life (20 Year minimum) AR coating on large area sheets of glass (up to 48 x 48 in.). The methods of production shall consist of applying a uniform film of sodium silicate to the sunlit surface of the glass followed by treatment with sulfuric acid.

Status:

A cost effective AR coating was developed for low iron soda-lime glass which increases light transmission from approximately 92% to aproximately 97%. Technical work is complete. The final report draft is 7 months past due date.

September 1980

TITLE: A/R Coating on Soda-Lime Glass
CONTRACT NUMBER: 955387

CONTRACTOR (NAME AND ADDRESS):
Motorola, Inc.
Semiconductor Group
5005 E. McDowell Rd.
Phoenix, AZ 95008
TELEPHONE: (602) 244-5511
PRINCIPAL INVESTIGATOR: E. Pasterik

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 354-4482
PROJECT ENGINEER: F. Bouquet

CURRENT CONTRACT PERIOD:
FROM: 03/79 **TO:** 04/80

PROBABLE PROJECT COMPLETION DATE: 06/80

AREA/TASK: Encapsulation

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 77,160	DOE
FY 80	$ -0-	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Develop and demonstrate a glass surface acid leach technique for producing an antireflection coating on glass. Evaluate its durability and soiling resistance.

Status:

The project is now complete. Characterization of coating optical performance as a function of process parameters demonstrated good optical transmission (as high as 99% at 0.46 nanometers wavelength). Chemical durability of the coating was good but it showed a lack of abrasion resistance as would be required for resistance to airborne dirt and routine cleaning.

The process technology is available and may be of interest in special applications in the future.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Processing Experiments with RTR Silicon Material

CONTRACT NUMBER: 955844

CONTRACTOR (NAME AND ADDRESS):
Motorola, Inc.
5005 E. McDowell Road
Phoenix, AZ 85008

TELEPHONE: (602) 244-5511

PRINCIPAL INVESTIGATOR: Dr. R. Pryor

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9402

PROJECT ENGINEER: C. Radics

CURRENT CONTRACT PERIOD:
FROM: 10/14/80 **TO:** 4/81

PROBABLE PROJECT COMPLETION DATE: 4/81

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE
80	100,000	DOE

SUMMARY:

The Contractor shall (1) develop a low-cost process sequence for the manufacture of solar cells from non-Czochralski (non-CZ) silicon sheet forms using Ribbon-to-Ribbon (RTR) substrates grown from Chemical Vapor Deposition (CVD) feedstock by lasser zone regrowth as developed, in part, under JPL Contract No. 954376. If possible, the Contractor shall use processes presently available to the Low-Cost Solar Array (LSA) Project for the production of solar cells from single crystal silicon wafers.

Status:

New Contract.

September 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Study Program for Encapsulation Materials Interface

CONTRACT NUMBER: 954739

CONTRACTOR (NAME AND ADDRESS):
Rockwell International Corporation
Science Center
P. O. Box 1085
Thousand Oaks, CA 91360
TELEPHONE: (904) 498-4545
PRINCIPAL INVESTIGATOR: D. H. Kaelble

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 354-3178
PROJECT ENGINEER: J. Moacanin

CURRENT CONTRACT PERIOD:
FROM: 03/77 **TO:** 12/81

PROBABLE PROJECT COMPLETION DATE: 12/81

AREA/TASK: Encapsulation

CONTRACT FUNDING:

FY	$	SOURCE:
77	30,000	DOE
78	103,700	DOE
79	99,660	DOE
80	92,400	DOE

SUMMARY:

Conduct a physical/chemical study of surface and interfacial degradation mechanisms in silicon solar cell encapsulation systems induced by the singular and combined effects of moisture temperature and UV radiation.

Status:

The mechanisms and rates of solar cell corrosion have been investigated as a function of environmental parameters (temperature/humidity) and module fabrication parameters (interface bonding and cell cracks). Two outdoor corrosion monitoring concepts have been developed, a passive corrosion current monitor and an AC impedance measurement technique.

During FY81, a field instrument for AC impedance measurement will be designed. The mechanism of enhanced corrosion effects in cracked solar cells and UV irradiated cells will be studied and related to long-term performance degradation.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Analysis of Solar Module Efficiencies
CONTRACT NUMBER: 955787

CONTRACTOR (NAME AND ADDRESS):
Science Applications, Inc.
1710 Goodridge Drive
McLean, Virginia 22102

TELEPHONE: (202) 821-4499
PRINCIPAL INVESTIGATOR: Dr. M. Knasel

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, California 91109
TELEPHONE: (213) 577-9324
PROJECT ENGINEER: P. Alexander

CURRENT CONTRACT PERIOD:
FROM: 6/26/80 **TO:** 2/81

PROBABLE PROJECT COMPLETION DATE: 2/81

AREA/TASK: Production Process and Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
80	42,340	DOE

SUMMARY:

Conduct analyses and construct appropriate models for the relationship between both cell and module efficiencies and optical variables.

Status:

The contract is on schedule and is scheduled for completion in February, 1981.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Phase 2 of the Array Automated Assembly Task
CONTRACT NUMBER: 954865

CONTRACTOR (NAME AND ADDRESS):
Sensor Technology, Inc. (Photowatt)
21012 Lassen Street
Chatsworth, CA 91311

TELEPHONE: (602) 894-9564
PRINCIPAL INVESTIGATOR: G. Jones

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109
TELEPHONE: (213) 577-9422
PROJECT ENGINEER: E. Drouet

CURRENT CONTRACT PERIOD:
FROM: 09/77 TO: 11/80

PROBABLE PROJECT COMPLETION DATE: 11/80

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

		SOURCE:
FY 77	$ 130,000	DOE
FY 78	$ 264,890	DOE
FY 79	$ 283,000	DOE
FY 80	$ 42,000	DOE
FY	$	

SUMMARY:

A process sequence shall be specified which, when automated, whould have the potential of mass producing silicon solar cell array modules encapsulated for protection against the Earth environment. This sequence shall be critically analyzed for cost effectiveness, quantity throughput and reproducibility of the product.

Status:

Contract completed, rough draft of final report accepted with corrections. Corrected version of final report due at JPL on or before November 30, 1980.

Comments:

Photowatt developed an automatic spray-on machine for applying Polymer dopants, AR coatings, and BSF. This equipment was delivered to the PP&E laboratory.

Under this contract it was determined that a wetting agent must be applied to texturized wafers in order to obtain a uniform AR coating.

The microwave study revealed that existing equipment limitations must be overcome before this approach can be more fully investigated. The additional effort required was shown to be at the research level and therefore are beyond the scope of this contract.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Development of Low-Cost Polysilicon Solar Cells

CONTRACT NUMBER: 955265

CONTRACTOR (NAME AND ADDRESS):
Sensor Technology, Inc. (Photowatt)
21012 Lassen St.
Chatsworth, CA 91311

TELEPHONE: (602) 894-9564

PRINCIPAL INVESTIGATOR: S. Rhee

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 577-9374

PROJECT ENGINEER: D. Burber

CURRENT CONTRACT PERIOD:
FROM: 12/78 **TO:** 3/80

PROBABLE PROJECT COMPLETION DATE: 10/80

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE
79	162,236	DOE
80	-0-	DOE

SUMMARY:

Investigate, develop and document improved methods for the production of low-cost, high energy-per-unit-area greater than three-inch (3") diameter polysilicon solar cells with a solar energy efficiency greater than or equal to ten percent (10%).

Status:

This contract is completed except for review of the second draft of the final report. During the course of this contract, it was shown that most standard cell processes were applicable to polycrystalline silicon wafers. Three different wafer vendor materials were evaluated: Wacker, Exotic Materials and Crystal Systems wafers were acceptable with Wacker being more readily available and more consistent. Ten percent (10%) cells were achieved using $POCl_3$ gettering, spray-on dopant and SIO AR coating.

September, 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Enhanced I.D. Slicing - Silicon Ingots

CONTRACT NUMBER: 955282

CONTRACTOR (NAME AND ADDRESS):
Siltec Corporation
3717 Haven Ave.
Menlo Park, CA 94025

TELEPHONE: (415) 365-8600

PRINCIPAL INVESTIGATOR: G. Fiegl

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 354-5782

PROJECT ENGINEER: T. Daud

CURRENT CONTRACT PERIOD:
FROM: 12/79 **TO:** 10/80

PROBABLE PROJECT COMPLETION DATE: 10/80

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE:
FY 79	$ 220,000	DOE
FY 80	$ 129,466	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Develop and demonstrate enhanced Internal Diameter (I.D.) Slicing technology for silicon ingots that will reduce the combined kerf and slice thickness in order to maximize silicon material utilization.

Status:

This effort, under the Neat-Term Implementation (Tsongas) has been completed on October 31, 1980. The goals for this effort were to achieve 25 slices/cm (minimum thickness of wafer, 250 μm) on 10 cm. diameter silicon ingot at 1 wafer/min achieving a blade life of 4000 wafers.

The contractor's approach was:

a) to demonstrate ingot rotation which was successfully done;

b) obtain low kerf I.D. blades, which was obtained by etching the blade core and diamond plating;

c) develop dynamic blade control with feed back loop which was successfully done to reduce blade deflection to fraction of a mil;

d) demonstrate a production run to achieve goals. This was not done successfully, yielding only 22 slices/cm at about 1/4 wafers per min., with a blade life of 200 to 300 wafers.

This failure has been attributed to the limitation of the saw and to a greater extent a limitation of ingot totation process, itself.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Phase 2 of the Array Automated Assembly Task
CONTRACT NUMBER: 954854

CONTRACTOR (NAME AND ADDRESS):
Solarex Corporation
1335 Piccard Drive
Rockville, MD 20850

TELEPHONE: (301) 948-0202
PRINCIPAL INVESTIGATOR: J. Anderson

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA
TELEPHONE: (213) 577-9422
PROJECT ENGINEER: L. Sanchez

CURRENT CONTRACT PERIOD:
FROM: 09/77 TO: 12/80

PROBABLE PROJECT COMPLETION DATE: 12/80

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
77	130,000	DOE
78	262,171	DOE
79	100,000	DOE
80	104,056	DOE

SUMMARY:

A process sequence shall be specified which, when automated, would have the potential of mass producing silicon solar cell array modules encapsulated for protection against the Earth environment. This sequence shall be critically analyzed for cost effectiveness, quantity throughput and reproducibility of the product.

Status:

Contract completed. All contract objectives met. Final Report has been accepted by JPL and will be distributed by Solarex by December 2, 1980.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Fabricate Block IV Modules
CONTRACT NUMBER: 955404

CONTRACTOR (NAME AND ADDRESS):
Solarex Corporation
1335 Piccard Drive
Rockville, MD 20850

TELEPHONE: (301) 948-0202
PRINCIPAL INVESTIGATOR: J. Wohlgemuth

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, California 91109

TELEPHONE: (213) 577-9214
PROJECT ENGINEER: D. Runkle

CURRENT CONTRACT PERIOD:
FROM: 5/21/79 **TO:** 2/81

PROBABLE PROJECT COMPLETION DATE: 2/81

AREA/TASK: Module Production

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 221,791	DOE
FY 80	$ -0-	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Design, fabricate, test, qualify, and deliver intermediate-load pre-production solar cell modules and residential-load pre-production solar cell modules. Prepare a standardized price estimate with supporting analyses and input data for the approved module design for each of the two types of modules, using the Solar Array Manufacturing Industry Simulation (SAMIS) computer program.

Status:

Modules produced to date have not passed the qualification testing. Failures include cell cracking under temperature cycling and mechanical cycling, separation of lamination and voltage breakdown during high-pot testing.

September, 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Module Experimental Process System Development Unit (MEPSDU)

CONTRACT NUMBER: 955902

CONTRACTOR (NAME AND ADDRESS):

Solarex Corporation
1335 Piccard Drive
Rockville, MD 20850

TELEPHONE: (301) 948-0202

PRINCIPAL INVESTIGATOR: J. Anderson

DIRECTING ORGANIZATION AND ADDRESS:

Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9563

PROJECT ENGINEER: J. W. Behm

CURRENT CONTRACT PERIOD:

FROM: 11/26/80 **TO:** 2/83

PROBABLE PROJECT COMPLETION DATE: 2/83

AREA/TASK: Production Process and Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
81	275,000	DOE

SUMMARY:

The contractor shall demonstrate the technical readiness of a cost-effective process sequence that has the potential for the production of flat-plate photovoltaic modules which meet a factory F.O.B. price goal in 1986 of 70¢ or less per Watt peak (1980$). This goal assumes operation of the module in an insolation of 100 mW/cm^2, at a temperature of 28° C and in a spectrum represented by AM-1. For this demonstration the Contractor shall (1) use material costs as projected in the SAMICS Cost Account Catalog and (2) assume operation of the modules under the conditions assumed in setting the goal.

Status:

New Contract.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Fabricate Block IV Modules

CONTRACT NUMBER: 955403

CONTRACTOR (NAME AND ADDRESS):

Solar Power Corporation
20 Cabot Road
Woburn, MA 01801

TELEPHONE: (617) 935-4600

PRINCIPAL INVESTIGATOR: D. Dilts

DIRECTING ORGANIZATION AND ADDRESS:

Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9214

PROJECT ENGINEER: D. Runkle

CURRENT CONTRACT PERIOD:

FROM: 6/13/79 **TO:** 12/80

PROBABLE PROJECT COMPLETION DATE: 12/80

AREA/TASK: Module Production

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 129,863	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

Design, fabricate, test, qualify, deliver pre-production solar cell modules which comply with requirements of JPL Document 5101-16 Rev. A, entitled, "Block IV Solar Cell Module Design and Test Specification for Intermediate Load Center Applications." Prepare also a standard price estimation for 10, 100, and 1000 KW of modules delivered in 1980.

Status:

Solar Power designed two innovative modules during the course of this contract. The first was discarded as being too expensive to fabricate and the second failed to pass the qualification program for Block IV modules.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Phase 2 of the Array Automated Assembly Task

CONTRACT NUMBER: 954853

CONTRACTOR (NAME AND ADDRESS):
Spectrolab, Inc.
12500 Gladstone Ave.
Sylmar, CA 91342

TELEPHONE: (213) 365-4611

PRINCIPAL INVESTIGATOR: W. Taylor

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 577-9324

PROJECT ENGINEER: P. Alexander

CURRENT CONTRACT PERIOD:

FROM: 09/77 **TO:** 11/80

PROBABLE PROJECT COMPLETION DATE: 11/80

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
77	250,000	DOE
78	455,734	DOE
79	408,000	DOE
80	226,716	DOE

SUMMARY:

A process sequence shall be specified which, when automated, would have the potential of mass producing silicon solar cell array modules encapsulated for protection against the Earth environment. This sequence shall be critically analyzed for cost effectiveness, quantity throughput and reproducibility of the product.

Status:

The contract is completed. The draft final report was reviewed and approved in October, 1980. Distribution of the final report is expected in November, 1980.

September, 1980

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Solar Cell Development, Fabrication and Analysis

CONTRACT NUMBER: 955055

CONTRACTOR (NAME AND ADDRESS):
Spectrolab, Inc.
12500 Gladstone Ave.
Sylmar, CA 91342

TELEPHONE: (213) 365-4611
PRINCIPAL INVESTIGATOR: J. Minahan

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 354-2190
PROJECT ENGINEER: S. Hyland

CURRENT CONTRACT PERIOD:
FROM: 08/78 **TO:** 9/80

PROBABLE PROJECT COMPLETION DATE: 9/80

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:		SOURCE:
FY 78	$ 75,000	DOE
FY 79	$ 110,823	DOE
FY 80	$ 109,826	DOE
FY	$	
FY	$	

SUMMARY:

Fabrication of silicon solar cells using standard and reproducible processes; reliable testing of the solar cells using standardized equipment and techniques; investigate, develop and utilize technologies appropriate and necessary for improving the efficiency of solar cells made from large area silicon sheets.

Status:

This contract was allowed to run out in September, 1980 at the end of Phase II due to lack of progress on the part of Spectrolab, both in developing baseline processes for certain materials and in delivering monthly and quarterly reports on time.

September, 1980

TITLE: High Resolution Low Cost Cell Contact Development **CONTRACT NUMBER:** 955725	
CONTRACTOR (NAME AND ADDRESS): Spectrolab, Inc. 12500 Gladstone Ave. Sylmar, CA 91342 **TELEPHONE:** (213) 365-4611 **PRINCIPAL INVESTIGATOR:** N. Mardesich	**DIRECTING ORGANIZATION AND ADDRESS:** Jet Propulsion Laboratory Low-Cost Solar Array Project (502-422) 4800 Oak Grove Dr. Pasadena, CA 91103 **TELEPHONE:** (213) 577-9225 **PROJECT ENGINEER:** B. Gallagher
CURRENT CONTRACT PERIOD: **FROM:** 06/80 **TO:** 03/81	**CONTRACT FUNDING:** **SOURCE:** FY 80 $ 100,000 DOE FY ___ $ ___ FY ___ $ ___ FY ___ $ ___ FY ___ $ ___
PROBABLE PROJECT COMPLETION DATE: 03/81	
AREA/TASK: Production Process & Equipment	

SUMMARY:

Demonstrate the technical and economic feasibility of the "MID-FILM" process for depositing solar cell collector grid metallization with a potential, when automated, of mass producing silicon solar cells at low-cost for use in solar cell array modules in terrestrial environments.

Status:

Spectrolab has successfully transferred the MIDFILM® process from Ferro Corp. (a Subcontractor) to their own facility. Silver based ink formulations have produced 5.3cm X5.3cm solar cells with efficienes greater than 13%. The program is on schedule and non-noble ink formulations are being explored.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design, Analysis, and Test Verification of Advanced Encapsulation Systems

CONTRACT NUMBER: 955567

CONTRACTOR (NAME AND ADDRESS): Spectrolab, Inc. 12500 Gladstone Ave. Sylmar, CA 91342 **TELEPHONE:** (213) 365-4611 **PRINCIPAL INVESTIGATOR:** Dr. W. Taylor	**DIRECTING ORGANIZATION AND ADDRESS:** Jet Propulsion Laboratory Low-Cost Solar Array Project (502-422) 4800 Oak Grove Dr. Pasadena, CA 91109 **TELEPHONE:** (213) 354-3188 **PROJECT ENGINEER:** E. Cuddihy

CURRENT CONTRACT PERIOD:
FROM: 11/79 **TO:** 11/81

PROBABLE PROJECT COMPLETION DATE: 11/81

AREA/TASK: Encapsulation

CONTRACT FUNDING:

FY	$	SOURCE:
80	358,000	DOE

SUMMARY:

Prepare a prototype encapsulation system design with recommended material selections and fabrication processes, including a detailed design analysis of the predicted optical, electrical, thermal, and structural performance of the recommended design.

Status:

During the initial year of this contract, Spectrolab has developed optical, thermal, electrical, and structural analytical computer models for the analysis and performance assessment of module encapsulation systems. Parametric and sensitivity studies have provided design and performance optimization criteria relative to encapsulent material selection and material dimensions.

During the second year material and module tests will be conducted to verify the analysis tools developed and prepare an optimized encapsulation system design.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Develop and Test Encapsulation Materials
CONTRACT NUMBER: 954521

CONTRACTOR (NAME AND ADDRESS): Spire Corporation Patriots Park Bedford, MA 01730 **TELEPHONE:** (617) 275-6000 **PRINCIPAL INVESTIGATOR:** Peter Younger	**DIRECTING ORGANIZATION AND ADDRESS:** Jet Propulsion Laboratory Low-Cost Solar Array Project (502-422) 4800 Oak Grove Drive Pasadena, CA 91109 **TELEPHONE:** (213) 354-3465 **PROJECT ENGINEER:** R. Holtze

CURRENT CONTRACT PERIOD:
FROM: 05/76 **TO:** 1/81

PROBABLE PROJECT COMPLETION DATE: 1/81

AREA/TASK: Encapsulation

CONTRACT FUNDING:

FY	$	SOURCE:
FY 76	$ 110,000	DOE
FY 77	$ 324,648	DOE
FY 78	$ 290,000	DOE
FY 79	$ 250,067	DOE
FY 80	$ 154,082	DOE

SUMMARY:

Develop and demonstrate electrostatic bonding as an integral glass encapsulation technique. Develop the fabrication hardware and scale-up design criteria for full-scale solar modules.

Status:

High efficiency mini-modules for field life testing have been delivered to JPL with ESB glass front and EVA back surface pottant.

Mini-modules with preformed (wire mesh) metallization have been fabricated with 9% module efficiency. Processing improvements will be made and additional mini-modules delivered during the year.

Specimens of low pressure ESB silicon wafer-to-glass have been fabricated. Complete active modules with interdigitated back contact cells will be fabricated during FY81.

Scale-up and large bonder design efforts have been postponed due to funding constraints.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Fabricate Block IV Modules

CONTRACT NUMBER: 955405

CONTRACTOR (NAME AND ADDRESS):
Spire Corporation
Patriots Park
Bedford, MA 01730

TELEPHONE: (617) 275-6000

PRINCIPAL INVESTIGATOR: Dr. P. Younger

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9214

PROJECT ENGINEER: D. Runkle

CURRENT CONTRACT PERIOD:
FROM: 5/22/79 **TO:** 2/80

PROBABLE PROJECT COMPLETION DATE: 9/80

AREA/TASK: Module Production

CONTRACT FUNDING:		SOURCE:
FY 79	$ 148.706	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

Design, fabricate, test, qualify, deliver preproduction solar cell modules which comply with requirements of JPL Document 5101-16 Rev. A, entitled, "Block IV Solar Cell Module Design and Test Specifications for Intermediate Load Center Applications." Prepare also a standardized price estimate for 10, 100, and 1000 kW of modules delivered in 1980.

Status:

All work under this contract has been accomplished. Modules have been fabricated, tested, qualified and delivered. Price estimates have been prepared.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Development and Fabrication of a Solar Cell Junction Processing System

CONTRACT NUMBER: 955640

CONTRACTOR (NAME AND ADDRESS):
Spire Corporation
Patriots Park
Bedford, MA 01730

TELEPHONE: (617) 275-6068
PRINCIPAL INVESTIGATOR: A. Armini

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena CA 91109

TELEPHONE: (213) 354-4792
PROJECT ENGINEER: D. Fitzgerald

CURRENT CONTRACT PERIOD:
FROM: 01/80 **TO:** 02/82

PROBABLE PROJECT COMPLETION DATE: 02/82

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE
80	865,000	DOE

SUMMARY:

Develop, construct, and deliver a junction processing system which shall be capable of producing solar cell junctions by means of ion implantation followed by pulsed electron beam annealing. The machine shall be capable of processing four (4) inch diameter single crystal Czochralski wafers at a rate of 10^7 wafers per year.

Status:

This contract has focused on the development of the pulsed electron beam anneal (PEBA) subsystem, during the past fiscal year. The PEBA design was completed in July after several months of experiments and analyses. Most of the parts for the PEBA were fabricated by the end of the FY80. The PEBA subsystem should be assembled by mid-December, 1980. Spire has collaborated with Brookes Bros., Nashua, NH to come up with a novel approach in transporting the silicon wafers in and out of the vacuum environment where the ion implantation and pulse anneal process will take place. They have developed a concept which allows continous wafer motion through the processor. This is performed by using two vacuum interlocks at both the entrance and exit ports. With this feature, one cassette load can be pumping down (venting up) while the other is being unloaded (loaded). A novel "Y" walking-beam approach at both ends allows this method to be used. Construction of the transport system will being in about one month.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Module Encapsulation Task

CONTRACT NUMBER: 954527

CONTRACTOR (NAME AND ADDRESS):
Springborn Laboratories, Inc.
Water Street
Enfield, CT 06082

TELEPHONE: (203) 749-8371

PRINCIPAL INVESTIGATOR: B. Baum

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 354-3188

PROJECT ENGINEER: E. Cuddihy

CURRENT CONTRACT PERIOD:
FROM: 5/76 **TO:** 08/80

PROBABLE PROJECT COMPLETION DATE: 08/82

AREA/TASK: Encapsulation

CONTRACT FUNDING:

FY	$	SOURCE:
76	175,000	DOE
77	110,480	DOE
78	190,000	DOE
79	100,000	DOE
80	121,666	DOE

SUMMARY:

Survey, screen and rank low-cost encapsulation material candidates. Develop and characterize most promising material systems and process which meet LSA cost and performance goals.

Status:

Candidate materials and module fabrication processes have been identified for each of the module encapsulation functional elements including covers, pottants, structural panels, back covers and edge seals. The list of candidates has been narrowed to the two or three most promising for each function. These candidates are undergoing intensive characterization and field testing relative to weatherability, photothermal stability and processibility.

These materials include low-iron termpered glass, ethylene vinylacetate, elastomeric acrylics, tedlar, acrylic films, mild steel and wood hardboard. Close industrial liaison through Springborn has encouraged voluntary participation of large industrial suppliers as material requirements and market potential have become more clearly specified.

Future work includes development of module surfacing treatments for soil resistance, material additives for improved photothermal stability of pottants and cover films, and design optimization for edge seals and gaskets.

September, 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silane to Silicon Process
CONTRACT NUMBER: 954334

CONTRACTOR (NAME AND ADDRESS):
Union Carbide Corporation or UCC Linde Div.
270 Park Avenue
New York, NY 10017
P.O. Box 44
Tonawanda, NY
14150

TELEPHONE: (716) 879-2582
PRINCIPAL INVESTIGATOR: H. Morihara

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-7428
PROJECT ENGINEER: G. Hsu

CURRENT CONTRACT PERIOD:
FROM: 10/75 **TO:** 12/82

PROBABLE PROJECT COMPLETION DATE: 12/82

AREA/TASK: Silicon Material

CONTRACT FUNDING:

FY	$	SOURCE:
76	205,000	DOE
77	328,379	DOE
78	851,621	DOE
79	1,236,000	DOE
80	4,354,000	DOE
		DOE

SUMMARY:

Conduct a program to establish the practicality of a process for the high-volume low-cost production of high-purity silicon capable of achieving the LSA photovoltaic silicon cost goal of $14 per kiogram (1980 dollars).

Status:

This Contract has demonstrated the technical feasibility of the silane-to-silicon process (Phase I) in laboratory process development units; and has delivered a comprehensive process design (Phase II) package of a 100 metric ton/year Experimental Process System Development Unit (EPSDU). The silicon product price (with 15% return-on-investment) is estimated to be less than $14 per kilogram in 1980 dollars.

Most of the silane production portions of the process are well established, whereas the silane-to-silicon portion is yet to be finalized. The baseline mode for silicon production in the EPSDU involves free-space reactor silane pyrolysis and melting/consolidation via silicon shotting. Critical supporting engineering developments are centered around these areas, along with a strong R & D back-up technology using the fluidized bed reactor to produce silicon granules instead of free-space reactor powders.

The effort is in a Phase III EPSDU (pilot plant) demonstration stage. The civil construction of the EPSDU started in October, 1980 at the E. Chicago, Indiana site. Major equipment and long-lead-time items have been ordered and are planned to be delivered on site by May, 1981. The initial EPSDU testing was originally anticipated to start around January, 1982. Limited by FY81 funding, the EPSDU operation schedule is estimated to be delayed for approximately 4 to 7 months. This contract is expected to deliver high-purity silicon after the middle of 1982.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Development of Synthetic Procedures for Polymeric Ultraviolet Stabilizers and Absorbers

CONTRACT NUMBER: 955531

CONTRACTOR (NAME AND ADDRESS):
University of Massachusetts
Office of Grant and Contract Administration
Graduate Research Center
Amherst, MA 01003
TELEPHONE: (413) 545-0433
PRINCIPAL INVESTIGATOR: Dr. Otto Vogl

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 354-5783
PROJECT ENGINEER: A. Gupta

CURRENT CONTRACT PERIOD:
FROM: 08/79 **TO:** 12/81

PROBABLE PROJECT COMPLETION DATE: 12/81

AREA/TASK: Encapsulation

CONTRACT FUNDING:

		SOURCE:
FY 79	$ 15,000	DOE
FY 80	$ 32,000	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Develop synthetic procedures for certain polymerizable ultraviolet stabilizers and absorbers and study their copolymerization with methyl and butyl esters of methacrylic acid.

Status:

Effort has concentrated on the synthesis and scale-up of the formulation for the UV absorber vinyl tinuvin. This functional monomer can be readily polymerized, copolymerized or graft copolymerized to achieve a permanent protective UV-stabilizing species in encapsulant pottants and cover films.

The synethesis procedures have been transferred to Springborn Labs. Studies on the synthesis of additional alternate UV absorbers will be conducted in 1981.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Determine Effects of Pressures of Reactant Gases
CONTRACT NUMBER: 955415

CONTRACTOR (NAME AND ADDRESS):
University of Missouri
215 University Hall
Columbia, MO 65211

TELEPHONE: (314) 341-4406
PRINCIPAL INVESTIGATOR: P.D. Ownby

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-6998
PROJECT ENGINEER: M. Hagan

CURRENT CONTRACT PERIOD:
FROM: 05/79 **TO:** 08/80

PROBABLE PROJECT COMPLETION DATE: 01/81

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE
79	20,000	DOE
80	24,799	DOE
81	49,799	DOE

SUMMARY:

Determination of effect of varying partial pressures of reactant gases, primarily oxygen, in a furnace atmosphere where molten silicon is in contact with die and container refractory materials, and determination of the extent of reaction between molten silicon and refractory materials at the interfacial reaction zones as a function of the partial pressure of the reactant gases.

Status:

UMR has visited Mobil-Tyco and JPL and measured the partial pressure of oxygen in their production and test facilities, respectively. The data obtained showed non-equilibrium conditions in both facilities, primarily because of reaction between oxygen and carbon refractories used in both facilities.

Visits have been scheduled to Westinghouse during November 10-14, 1980, and to Hamco during December 15-19, 1980 to measure oxygen partial pressures in the dendritic web and Czochralski growth facilities, respectively. Correlative laboratory studies will be made at UMR and the results will be presented in the contract final report.

September 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Analysis and Evaluation of Processes and Equipment

CONTRACT NUMBER: 954796

CONTRACTOR (NAME AND ADDRESS):
The Trustees of the University of
Pennsylvania
3451 Walnut St. I6
Philadelphia, PA 19104
TELEPHONE: (215) 243-4822
PRINCIPAL INVESTIGATOR: M. Wolfe

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 354-6308
PROJECT ENGINEER: P. Stella

CURRENT CONTRACT PERIOD:
FROM: 07/77 **TO:** 11/80

PROBABLE PROJECT COMPLETION DATE: 2/81

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

FY	$	SOURCE
77	114,618	DOE
78	99,667	DOE
79	41,780	DOE
80	150,821	DOE

SUMMARY:

Perform expert analysis and critical evaluation of processes and equipment, proposed or designed, for the high-volume production of modules.

Status:

The impact of solar cell efficiency on the overall system specific cost ($ per watt) has been examined and described in terms of a nomograph. From this, the cost that can be allocated to any given process so as to satisfy overal system cost requirements, can be determined once the process impact on cell efficiency is established. Areas of cell processing examined to date, include methods for junction formation, contact metallization, and AR coating.

A no cost extension through February, 1981 has been initiated.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Modeling of Photodegradation in Solar Cell Modules

CONTRACT NUMBER: 955591

CONTRACTOR (NAME AND ADDRESS):
University of Toronto
Office of Research Administration
Simcoe Hall
Toronto, Ontario, Canada H5S-1A1
TELEPHONE: (416) 978-3591
PRINCIPAL INVESTIGATOR: Prof. James Guillet

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 354-5783
PROJECT ENGINEER: A. Gupta

CURRENT CONTRACT PERIOD:
FROM: 01/80 **TO:** 12/80

PROBABLE PROJECT COMPLETION DATE: 12/80

AREA/TASK: Encapsulation

CONTRACT FUNDING:

		SOURCE:
FY 77	$ 25,000	DOE
FY 78	$ 25,800	DOE
FY 79	$ 26,290	DOE
FY 80	$ 42,000	DOE
FY	$	

SUMMARY:

Develop an analytical model of photodegradation of ethylene vinyl acetate (EVA) using real time test data on EVA encapsulated solar cell modules and laboratory data on EVA films both free standing, under glass or other transparent covers/ barriers.

Status:.

A computer simulation program has been developed to predict long-term chemical changes based on generalized photooxidation mechanisms. An experimental validation program has been planned and initially will be donducted with simple liquid alkanes using sensitive analytical probes to obtain required photoxidation data after short-term outdoor exposure.

BEST DOCUMENT AVAILABLE

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Investigation of Photovoltaic Array and Module Safety Requirements

CONTRACT NUMBER: 955392

CONTRACTOR (NAME AND ADDRESS):
Underwriters Laboratories, Inc.
1285 Walt Whitman Rd.
Melville, Long Island, NY 11746

TELEPHONE: (516) 271-6200

PRINCIPAL INVESTIGATOR: A. Levins

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109

TELEPHONE: (213) 577-9118

PROJECT ENGINEER: R. Sugimura

CURRENT CONTRACT PERIOD:

FROM: 05/79 **TO:** 09/81

PROBABLE PROJECT COMPLETION DATE: 09/81

AREA/TASK: Engineering

CONTRACT FUNDING:

FY	$	SOURCE:
79	65,730	DOE
80	54,100	DOE

SUMMARY:

Provide engineering services and other necessary support, as required, in the development of safety requirements for photovoltaic arrays for private sector use.

Status:

Phase I: The Draft Final is in typing at Underwriters Laboratories (U.L.) JPL is currently reviewing a draft of a proposed U.L. Standard for Safety for Photovoltaic Modules and Panels.

Phase II: Work has just begun on this phase. U.L. has made a site visit to Mead, Nebraska and taken some data with respect to soil conditions in conjunction with the grounding network designs.

September, 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Solar Cell Grade Silicon Definition

CONTRACT NUMBER: 954331

CONTRACTOR (NAME AND ADDRESS):
Westinghouse Electric Corporation
1310 Beulah Road
Pittsburgh, PA 15235

TELEPHONE: (412) 256-3235

PRINCIPAL INVESTIGATOR: R. S. Hopkins

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 577-9092

PROJECT ENGINEER: A. Yamakawa

CURRENT CONTRACT PERIOD:

FROM: 10/75 **TO:** 07/81

PROBABLE PROJECT COMPLETION DATE: 07/81

AREA/TASK: Silicon Material

CONTRACT FUNDING:

		SOURCE:
FY 76	$ 341,521	DOE
FY 77	$ 544,950	DOE
FY 78	$ 467,000	DOE
FY 79	$ 446,000	DOE
FY 80	$ 290,701	DOE

SUMMARY:

Define the effects of impurities, various thermochemical processes, and impurity-process interactions on the performance of terrestrial silicon solar cells.

Status:

Phase III of this contract was completed and the final report issued. The subjects treated are methods to measure and evaluate impurity effects in silicon, comprehensive tabulations of data accumulated during the study, effects of various metallic impurities introduced singly or in combination into Czochralski, float zone, and polycrystalline silicon ingots and into silicon ribbons grown by the dendritic web method, and an analytical model for predicting the effects of impurities on solar cell performances.

Effort was begun on Phase IV, which includes study of impurity effects in polycrystalline silicon, identification of impurity thresholds for high-efficiency cells, assessment of process effects on impurity-doped cells, and identification of long-term impurity effects. It was found that the threshold for ingot structural breakdown is lower for polycrystalline growth than when growing single crystals, at least for the impurities iron, titanium, vanadium, chromium, and molybdenum.

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Web Dendritic Process Development
CONTRACT NUMBER: 954654

CONTRACTOR (NAME AND ADDRESS):
Westinghouse Electric Corporation
Beulah Road
Pittsburgh, PA 15235

TELEPHONE: (412) 256-3666
PRINCIPAL INVESTIGATOR: C. Duncan

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502/422)
4800 Oak Grove Drive
Pasadena, CA 91109
TELEPHONE: (213) 354-7200
PROJECT ENGINEER: A. Morrison

CURRENT CONTRACT PERIOD:
FROM: 04/77 **TO:** 11/80

PROBABLE PROJECT COMPLETION DATE: 11/80

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

FY	$	SOURCE
77	350,000	DOE
78	772,869	DOE
79	771,715	DOE
80	565,708	DOE

SUMMARY:

To develop methods of production of large areas of silicon sheet by the Web Dendrite Process. The growth process methods to be developed are to be directed toward minimum cost processing of silicon into sheet of a quality suitable for producing solar cells with a terrestrial efficiency greater than twelve percent and having potential to be scaled for large-quantity production.

Status:

A new CPFF completion type contract (955843) calling for the final design definition and construction of the prototype TR ribbon growth machine was just signed. This commitment was made just as a 50 kw Westinghouse funded pilot production facility was being completed, and automatic melt level control was demonstrated on the LASS contract 954654, now terminated.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Silicon Dendritic Web Material Process Development
CONTRACT NUMBER: 955624

CONTRACTOR (NAME AND ADDRESS):
Westinghouse Electric Corporation
1310 Beulah Road
Pittsburgh, PA 15235
TELEPHONE: (412) 256-3682
PRINCIPAL INVESTIGATOR: P. Rai-Choudhury

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Dr.
Pasadena, CA 91109
TELEPHONE: (213) 577-9225
PROJECT ENGINEER: B. Gallagher

CURRENT CONTRACT PERIOD:
FROM: 03/80 TO: 1/81

PROBABLE PROJECT COMPLETION DATE: 1/81

AREA/TASK: Production Process & Equipment

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 193,615	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

Conduct a dendritic web development program to produce and deliver six meters of dendritic web per month (a total of thirty-six meters); determine conditions required to achieve a high yield of ultrasonic bonds on thick dendritic web; demonstrate the applicability of ultrasonic seam welding to the web; perform mechanical reliability tests on solar cell modules; determine the suitability of ethylene vinyl acetate and polyvinyl butyral as encapsulants for dendritic web material; produce and deliver four modules 30 cm x 60 cm in size using best technique available at end of first two months of the program; perform a cost analysis of a conceptual factory using dendritic web as the input sheet material; update SAMICS Format A data as processes are analyzed and completed.

Status:

The ultrasonic bonding process and the encapsulation process utilizing either ethylene vinyl autate or polyvinyl butyral have been successfully developed and are considered complete.

Technical problems encountered in the web growth facility have delayed both the dendtritic web delivery and the delivery of the four modules. Both are due to be delivered in the second quarter of 1981.

September, 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Dendritic Web Process Development

CONTRACT NUMBER: 955843

CONTRACTOR (NAME AND ADDRESS):
Westinghouse Electric Corporation
1310 Beulah Road
Pittsburgh, Pennsylvania 15235

TELEPHONE: (412) 256-3666

PRINCIPAL INVESTIGATOR: S. Duncan

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109

TELEPHONE: (213) 354-7200

PROJECT ENGINEER: A. Morrison

CURRENT CONTRACT PERIOD:
FROM: 10/22/80 TO: 1/82

PROBABLE PROJECT COMPLETION DATE: 1/82

AREA/TASK: Large Area Silicon Sheet

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 192,466	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The Contractor shall provide properly qualified personnel within appropriate scientific, engineering and technical classifications to design and fabricate a prototype web growth machine to complete process testing to meet the Low-Cost Solar Array Project (LSA) technology readiness goals. Development shall be directed toward a web growth process capable of producing silicon sheet suitable for use as low-cost solar cells with a terrestrial efficiency greater than fifteen percent (15%) and having potential to be scaled for large quantity. The cost goal is less than $700 (1980$) per peak kilowatt by 1985. The goals of this program are:

- o Automated growth period greater than 65 hours with melt-replenishment and area growth rate of greater than 25cm^2/min.
- o Length of web crystal greater than ten (10) meters.
- o Dislocation density below 10^4 /cm^2
- o Resistivity of web between 1 and 3 ohm-cm, p-type, in all web crystals.
- o Terrestrial solar cell efficiency greater than fifteen percent (15%).

Status:

New Contract.

September 1980

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Module Experimental Process System Development Unit (MEPSDU)

CONTRACT NUMBER: 955909

CONTRACTOR (NAME AND ADDRESS):
Westinghouse Electric Corporation
Advanced Energy Systems Division
P. O. Box 10864
Pittsburgh, PA 15236
TELEPHONE: (412) 256-5485
PRINCIPAL INVESTIGATOR: R. Campbell

DIRECTING ORGANIZATION AND ADDRESS:
Jet Propulsion Laboratory
Low-Cost Solar Array Project (502-422)
4800 Oak Grove Drive
Pasadena, CA 91109
TELEPHONE:
PROJECT ENGINEER:

CURRENT CONTRACT PERIOD:
FROM: 11/26/80 **TO:** 2/83

PROBABLE PROJECT COMPLETION DATE: 2/83

AREA/TASK: Production Process and Equipment

CONTRACT FUNDING:

FY	$	SOURCE:
81	275,000	DOE

SUMMARY:

The Contractor shall demonstrate the technical readiness of a cost-effective process sequence that has the potential for the production of flat-plate photovoltaic modules which meet a factory F.O.B. price goal in 1986 of 70¢ or less per Watt peak (1980$). This goal assumes operation of the module in an insolation of 100 mW/cm^2, at a temperature of 28° C and in a spectrum represented by Air Mass-1 (AM-1). For this demonstration the Contractor shall (1) use material costs as projected in the SAMICS Cost Account Catalog and (2) assume operation of the modules under the conditions assumed in setting the goal.

Status:

New Contract.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

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JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Flywheel System Cost Study

CONTRACT NUMBER: CX-2613

CONTRACTOR (NAME AND ADDRESS):

Airesearch Mfg. Co. of California
Div. of Garrett Corporation
2525 West 190th Street
Torrance, CA 90509

TELEPHONE:

PRINCIPAL INVESTIGATOR: H. Morgan

DIRECTING ORGANIZATION AND ADDRESS:

M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 11/16/79 **TO:** 2/10/80

PROBABLE PROJECT COMPLETION DATE: 2/10/80

AREA/TASK: Flywheel Technology Development

CONTRACT FUNDING:

FY	$	SOURCE:
80	24,800	DE-AC02-76ET-20279

SUMMARY:

Multiple awards were made to obtain estimates for production costs relating to flywheel energy storage and conversion systems intended for use with photovoltaic power systems for residential and intermediate load center applications.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design & Fabrication of a Residential Prototype System in the Northeast

CONTRACT NUMBER: CX-2839

CONTRACTOR (NAME AND ADDRESS):
Conti and Donahue, Inc.
239 Commercial Street
West Lynn, MA 01905

TELEPHONE:

PRINCIPAL INVESTIGATOR: T. S. Farrell

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 7/15/80 TO: 9/30/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: NE RES Prototype Systems

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 33,190	DE-AC02-76ET-20279
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

As part of the DOE National Photovoltaic Program Multi-year Plan, multiple awards were made for the detailed design, fabrication, and subsequent maintenance of prototype residential photovoltaic power systems installed and operated at the Northeast Residential Experiment Station in Concord, Mass. This procurement is for construction of the first prototype unit designed by Lincoln Laboratory. As will the several other prototype units, this system comprises the full-size photovoltaic array as would be used in a lived-in residence; the balance of system (BOS) components; the roofing or siding on which the collector is installed; only enough other structure to enclose and house the BOS, instrumentation and load duplicating equipment; and heating; ventilating and lighting equipment as necessary. Each prototype unit will establish data which will be used to gain an understanding of residential energy use.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: System Integration Work on 100 kWp PV Power System

CONTRACT NUMBER: BX-374

CONTRACTOR (NAME AND ADDRESS): Ford, Bacon & Davis Utah, Inc. P.O. Box 8009 375 Chipeta Way Salt Lake City, Utah 84108	**DIRECTING ORGANIZATION AND ADDRESS:** M.I.T. Lincoln Laboratory P.O. Box 73 Lexington, MA 02173
TELEPHONE:	**TELEPHONE:** 617-862-5500 ext. 213
PRINCIPAL INVESTIGATOR: L. Walker	**PROJECT ENGINEER:** M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 10/1/79 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 12/31/83

AREA/TASK: Natural Bridges National Monument

CONTRACT FUNDING:

FY	$	SOURCE:
79	1,379,928	EY-76-C-02-4094-A002
80	448,966	DE-AC02-76ET-20279

SUMMARY:

A 100 kWp photovoltaic array system was completed in June 1980 at the Natural Bridges National Monument in Utah. This installation is currently the largest flat-plate system in the world and supplies the diversified electrical load for the Park residences, visitor center and maintenance area. A contract for maintenance of the system will continue for a period of three years.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design & Fabrication of a Residential Prototype System in the Northeast

CONTRACT NUMBER: BX-566

CONTRACTOR (NAME AND ADDRESS):
General Electric Co.
Valley Forge Space Center
P.O. Box 8661
Philadelphia, PA 19101

TELEPHONE:

PRINCIPAL INVESTIGATOR: James Marler

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 6/18/80 **TO:** 12/31/81

PROBABLE PROJECT COMPLETION DATE: 12/31/81

AREA/TASK: NE RES Prototype Systems

CONTRACT FUNDING:

		SOURCE:
FY 81	$ 357,368	DE-AC02-76ET-20279
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

As part of the DOE National Photovoltaic Program Multi-year Plan, multiple awards were made for the detailed design, fabrication, and subsequent maintenance of prototype residential photovoltaic power systems installed and operated at the Northeast Residential Experiment Station in Concord, Mass. These prototype systems comprise the full-size photovoltaic array as would be used in a lived-in residence; the balance of system (BOS) components; the roofing or siding on which the collector is installed; only enough other structure to enclose and house the BOS, instrumentation and load duplicating equipment; and heating, ventilating and lighting equipment as necessary. Each prototype unit will establish data which will be used to gain an understanding of residential energy use.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Site Preparation for the Northeast Residential Experiment Station (Phase II)

CONTRACT NUMBER: BX-560

CONTRACTOR (NAME AND ADDRESS):

Horn Building Co., Inc.
31 Smith Place
Cambridge, MA 02138

TELEPHONE:

PRINCIPAL INVESTIGATOR: R. Grammont

DIRECTING ORGANIZATION AND ADDRESS:

M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 5/21/80 **TO:** 7/21/80

PROBABLE PROJECT COMPLETION DATE: 7/21/80

AREA/TASK: Northeast Residential Experiment Station

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 132,900	DE-AC02-76ET-20279
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The Northeast Residential Experiment Station (NE RES) is part of a long range Department of Energy plan to foster the development and implementation of solar photovoltaic systems as an alternative means of providing electrical energy at low cost to family residences throughout the country.

The initial objective of the plan is to establish Residential Experimental Stations in different climatic regions of the country where prototype facilities will be built for demonstrating different types of solar photovoltaic systems. The systems are to be tested and evaluated against simulated domestic loading under local climatic conditions before being applied to actual residences in the surrounding communities. The experimental station for the Northeast region of the country is located in Concord, Massachusetts.

Phase II site preparation included the construction of foundations on which to mount prototype systems for testing and evaluation, roadways, cable trenches and utilities to support these experimental systems.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Site Preparation for the Northeast Residential Experiment Station (Phase I)

CONTRACT NUMBER: BX-543

CONTRACTOR (NAME AND ADDRESS): J. J. Cronin Co. 60 Winter Street North Reading, MA 01864	**DIRECTING ORGANIZATION AND ADDRESS:** MIT Lincoln Laboratory P.O. Box 73 Lexington, MA 02173
TELEPHONE: (617) 664-3101	**TELEPHONE:** (617) 862-5500 X213
PRINCIPAL INVESTIGATOR: J. F. Canavan	**PROJECT ENGINEER:** M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 4/14/80 **TO:** 6/13/80

PROBABLE PROJECT COMPLETION DATE: 6/13/80

AREA/TASK:
Northeast Residential Experiment Station

CONTRACT FUNDING:

FY	$	SOURCE
80	107,500	DE-AC02-76ET-20279

SUMMARY:

The Northeast Residential Experiment Station (NE RES) is part of a long-range Department of Energy plan to foster the development and implementation of solar photovoltaic systems as an alternative means of providing electrical energy at low cost to family residences throughout the country.

The initial objective of the plan is to establish Residential Experimental Stations in defferent climatic regions of the country where prototype facilities will be built for demonstrating different types of solar photovoltaic systems. The systems are to be tested and evaluated against simulated domestic loading under local climatic conditions before being applied to actual residences in the surrounding communities. The experimental station for the Northeast region of the country is located in Concord, Massachusetts.

Phase I site preparation included land grading, surface drainage and access roadways for the construction of foundations on which to mount prototype systems for testing and evaluation. (See MIT Lincoln Laboratory BX-560 for Phase II site preparation.)

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design, Installation and Evaluation of Residential Grid-Connected Photovoltaic System

CONTRACT NUMBER: BX-542

CONTRACTOR (NAME AND ADDRESS):

John F. Long Properties, Inc.
P.O. Box 14029
Phoenix, AZ 85063

TELEPHONE:

PRINCIPAL INVESTIGATOR: John F. Long

DIRECTING ORGANIZATION AND ADDRESS:

M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 3/31/80 **TO:** 3/31/81

PROBABLE PROJECT COMPLETION DATE: 3/31/81

AREA/TASK: Innovative Photovoltaic Applications for Residences

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 200,000	DE-AC02-76ET-20279
FY 81	$ 60,499	DE-AC02-76ET-20279
FY	$	
FY	$	
FY	$	

SUMMARY:

A grid-connected, experimental photovoltaic system was designed, fabricated and installed on a residence in Phoenix during the summer of 1980. The system was designed to supply the total electric energy requirements on an annual average basis, of a typical Phoenix residence designed to include passive solar and energy conservation features. Initial defects in the system are currently being corrected, and the performance of the system will be monitored in FY81.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Flywheel System Cost Study

CONTRACT NUMBER: CX-2615

CONTRACTOR (NAME AND ADDRESS):
Kelsey-Hayes Corporate R&D Center
2500 Green Road
Ann Arbor, MI 48105

TELEPHONE:

PRINCIPAL INVESTIGATOR: H. Linkner

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 11/16/79 **TO:** 2/10/80

PROBABLE PROJECT COMPLETION DATE: 2/10/80

AREA/TASK: Flywheel Technology Development

CONTRACT FUNDING:

FY	$	SOURCE:
80	25,000	DE-AC02-76ET-20279

SUMMARY:

Multiple awards were made to obtain estimates for production costs relating to flywheel energy storage and conversion systems intended for use with photovoltaic power systems for residential and intermediate load center applications.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Residential Energy Studies

CONTRACT NUMBER: BX-561

CONTRACTOR (NAME AND ADDRESS):
M.I.T. Energy Laboratory
Cambridge, MA 02139

TELEPHONE: 617-253-3408

PRINCIPAL INVESTIGATOR: R. Tabors

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M.D. Pope

CURRENT CONTRACT PERIOD:

FROM: 7/3/80 **TO:** 9/30/80

PROBABLE PROJECT COMPLETION DATE: 4/30/81

AREA/TASK: Residential Systems Support

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 105,000	DE-AC02-76ET 20279
FY 81	$ 45,000	
FY	$	
FY	$	
FY	$	

SUMMARY:

Successful development of a residential photovoltaic systems market will depend on both the nature of the new technology being developed and the behavior of the housing markets into which that technology is to be introduced. The objective of this research activity is to identify the information needs of the DOE Residential Project with regard to the size and composition of regional housing markets and to propose procedures for meeting those needs in accordance with the DOE Residential Application Implementation Plan.

BEST DOCUMENT AVAILABLE

TITLE: Establish and Operate the Southwest Residential Experiment Station

CONTRACT NUMBER: BX-554

CONTRACTOR (NAME AND ADDRESS): New Mexico Solar Energy Institute New Mexico State University Box 350L Las Cruces, NM 88003 TELEPHONE: PRINCIPAL INVESTIGATOR: E. Lumsdaine	DIRECTING ORGANIZATION AND ADDRESS: M.I.T. Lincoln Laboratory P.O. Box 73 Lexington, MA 02173 TELEPHONE: 617-862-5500 ext. 213 PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:
FROM: 5/2/80 TO: 9/30/80

PROBABLE PROJECT COMPLETION DATE: 9/30/81

AREA/TASK:
Southwest Residential Experiment Station

CONTRACT FUNDING:

FY	$	SOURCE:
80	171,027	DE-AC02-76ET-2027

SUMMARY:

The Southwest Residential Experiment Station (SW RES) is part of a long-range Department of Energy plan to foster the development and implementation of solar photovoltaic systems as an alternative means of providing electrical energy at low cost to family residences throughout the country.

The initial objective of the plan is to establish Residential Experimental Stations in different climatic regions of the country where prototype facilities will be built for demonstrating different types of solar photovoltaic systems. The systems are to be tested and evaluated against simulated domestic loading under local climatic conditions before being applied to actual residences in the surrounding communities. The experimental station for the Southwest region of the country is located at the New Mexico Solar Institute in Las Cruces.

During the first phase of this activity, the Operator will provide the site management for prototype system assembly and will conduct a one- to two-year evaluation of each prototype system. The Operator is also responsible for maintaining the entire SW RES, will use the prototype systems as a means to educate and inform all interested parties of the capabilities of photovoltaic residential systems, and will assess the feasibility of proceeding to a lived-in initial systems evaluation experiment (ISEE) based on the performance of each prototype system.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Fabrication of a Residential Prototype System in the Northeast

CONTRACT NUMBER: BX-568

CONTRACTOR (NAME AND ADDRESS):
Solarex Corporation
Rockville, Maryland

TELEPHONE:

PRINCIPAL INVESTIGATOR: John Goldsmith

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M.D. Pope

CURRENT CONTRACT PERIOD:
FROM: 7/15/80 TO: 12/31/80

PROBABLE PROJECT COMPLETION DATE: 12/31/80

AREA/TASK: NE RES Prototype Systems

CONTRACT FUNDING:		SOURCE:
FY 80	$ 189,220	DE-AC02-76ET-20279
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

As part of the DOE National Photovoltaic Program Multi-year Plan, multiple awards were made for the detailed design, fabrication, and subsequent maintenance of prototype residential photovoltaic power systems installed and operated at the Northeast Residential Experiment Station in Concord, Mass. These prototype systems comprise the full-size photovoltaic array as would be used in a lived-in residence; the balance of system (BOS) components; the roofing or siding on which the collector is installed; only enough other structure to enclose and house the BOS, instrumentation and load duplicating equipment; and heating, ventilating and lighting equipment as necessary. Each prototype unit will establish data which will be used to gain an understanding of residential energy use.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Solar Photovoltaic Modules

CONTRACT NUMBER: BX-555

CONTRACTOR (NAME AND ADDRESS):

Solarex Corporation
1335 Piccard Drive
Rockville, MD 20850

TELEPHONE: (301) 948-0202

PRINCIPAL INVESTIGATOR: John Goldsmith

DIRECTING ORGANIZATION AND ADDRESS:

M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 4/23/80 TO: 9/30/80

PROBABLE PROJECT COMPLETION DATE: 9/30/80

AREA/TASK: PV/T Components

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 197,569	DE-AC02-76ET-20279
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

In accordance with the U.S. Department of Energy Residential Program, photovoltaic modules were procured for installation on the first prototype system and the first ISEE (initial systems evaluation experiment) in the Northeast. Procurement of approximately 15 kilowatts peak power was based on latest available solar cell technology.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Flywheel System Cost Study

CONTRACT NUMBER: CX-2614

CONTRACTOR (NAME AND ADDRESS):
Theodore Barry & Associates
1520 Wilshire Boulevard
Los Angeles, CA 90017

TELEPHONE:

PRINCIPAL INVESTIGATOR:

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M.D. Pope

CURRENT CONTRACT PERIOD:

FROM: 11/16/79 **TO:** 2/10/80

PROBABLE PROJECT COMPLETION DATE: 2/10/80

AREA/TASK: Flywheel Technology Development

CONTRACT FUNDING:

FY	$	SOURCE:
80	25,000	DE-AC02-76ET-20279

SUMMARY:

Multiple awards were made to obtain estimates for production costs relating to flywheel energy storage and conversion systems intended for use with photovoltaic power systems for residential and intermediate load center applications.

TITLE: Design & Fabrication of a Residential Prototype System in the Northeast

CONTRACT NUMBER: BX-569

CONTRACTOR (NAME AND ADDRESS):
TriSolar Corporation
6 Alfred Circle
Bedford, MA 01730

TELEPHONE: 617-275-1200

PRINCIPAL INVESTIGATOR: R. W. Matlin

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:

FROM: 6/27/80 TO: 12/31/81

PROBABLE PROJECT COMPLETION DATE: 12/31/81

AREA/TASK: NE RES Prototype Systems

CONTRACT FUNDING: SOURCE:

FY 80	$ 324,940	DE-AC02-76ET-20279
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

As part of the DOE National Photovoltaic Program Multi-year Plan, multiple awards were made for the detailed design, fabrication, and subsequent maintenance of prototype residential photovoltaic power systems installed and operated at the Northeast Residential Experiment Station in Concord, Mass. These prototype systems comprise the full-size photovoltaic array as would be used in a lived-in residence; the balance of system (BOS) components; the roofing or siding on which the collector is installed; only enough other structure to enclose and house the BOS, instrumentation and load duplicating equipment; and heating, ventilating and lighting equipment as necessary. Each prototype unit will establish data which will be used to gain an understanding of residential energy use.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: A Research Experiment in Rooftop Mounting of Photovoltaic Systems on Lived-in Units in Hawaii

CONTRACT NUMBER: BX-547

CONTRACTOR (NAME AND ADDRESS):
University of Hawaii at Manoa
Hawaii Natural Energy Institute
Honolulu, Hawaii

TELEPHONE:

PRINCIPAL INVESTIGATOR: D. Richard Neill

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M.D. Pope

CURRENT CONTRACT PERIOD:

FROM: 6/24/80 TO: 9/30/80

PROBABLE PROJECT COMPLETION DATE: 6/30/81

AREA/TASK: Innovative PV Applications for Residences

CONTRACT FUNDING:

FY	$	SOURCE:
80	100,000	DE-AC02-76ET-20279
81	185,264	DE-AC02-76ET-20279

SUMMARY:

This experiment involves retrofitting two existing residences in Hawaii with current state-of-the-art photovoltaic cells and installing on a third, as yet unbuilt unit a next-generation batten-seam roof photovoltaic system. All three systems will be utility interactive, and thus contain no on-site storage.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Operation and Maintenance of 25-kW PV Power Station

CONTRACT NUMBER: BX-192

CONTRACTOR (NAME AND ADDRESS):
University of Nebraska-Lincoln
Lincoln, Nebraska

TELEPHONE:

PRINCIPAL INVESTIGATOR: P. E. Fischbach

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M.D. Pope

CURRENT CONTRACT PERIOD:

FROM: 1/1/80 TO: 12/31/80

PROBABLE PROJECT COMPLETION DATE: 12/31/80

AREA/TASK: Nebraska Agricultural Test Facility

CONTRACT FUNDING:

		SOURCE:
FY 77	$ 146,358	EY-76-C-02-4094-A002
FY 78	$ 102,724	EY-76-C-02-4094-A002
FY 79	$ 123,085	EY-76-C-02-4094-A002
FY 80	$ 65,000	DE-AC02-76ET-20279
FY	$	

SUMMARY:

This contract is for the continued operation and maintenance of the 25-kW solar-cell powered system located at the University of Nebraska's Agricultural Site in Mead, Nebraska. The PV system is used for crop irrigation and drying. A variety of PV-related experiments was performed, including production of fertilizer using a PV-powered nitrogen generator. Experimentation and data collection activities continue. Publication of an Operations Manual is planned.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Solar Photovoltaic/Thermal Residential Experiment

CONTRACT NUMBER: CX-2703

CONTRACTOR (NAME AND ADDRESS):

University of Texas at Arlington
P.O. Box 19145
Arlington, TX 76019

TELEPHONE:

PRINCIPAL INVESTIGATOR: Q. S. Mathews

DIRECTING ORGANIZATION AND ADDRESS:

M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M.D. Pope

CURRENT CONTRACT PERIOD:

FROM: 10/1/79 **TO:** 8/31/80

PROBABLE PROJECT COMPLETION DATE: 8/31/80

AREA/TASK: Solar Photovoltaic/Thermal Energy

CONTRACT FUNDING:		SOURCE:
FY 80	$ 57.4 K	DE AC02-76ET 20279
FY 80	$ 52.5 K	DE AS02-77CS 34577
FY	$	
FY	$	
FY	$	

SUMMARY:

To investigate the application of combined photovoltaic/thermal collectors to roof-area-limited residences, the University of Texas was contracted to install a prototype system on an experimental residence at the UTA. A detailed study was conducted to measure and evaluate the electrical performance of the system, and a report of the results is to be published in October 1980.

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Design and Fabrication of a Residential Prototype System in the Northeast

CONTRACT NUMBER: BX-567

CONTRACTOR (NAME AND ADDRESS):
Westinghouse Electric Corp.
Power Systems Co.
P.O. Box 10864
Pittsburgh, PA 15236

TELEPHONE:

PRINCIPAL INVESTIGATOR: M. T. Johnson

DIRECTING ORGANIZATION AND ADDRESS:
M.I.T. Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

TELEPHONE: 617-862-5500 ext. 213

PROJECT ENGINEER: M. D. Pope

CURRENT CONTRACT PERIOD:
FROM: 6/18/80 **TO:** 12/31/81

PROBABLE PROJECT COMPLETION DATE: 12/31/81

AREA/TASK: NE RES Prototype Systems

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 353,000	DE-AC02-76ET-20279
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

As part of the DOE National Photovoltaic Program Multi-year Plan, multiple awards were made for the detailed design, fabrication, and subsequent maintenance of prototype residential photovoltaic power systems installed and operated at the Northeast Residential Experiment Station in Concord, Mass. These prototype systems comprise the full-size photovoltaic array as would be used in a lived-in residence; the balance of system (BOS) components; the roofing or siding on which the collector is installed; only enough other structure to enclose and house the BOS, instrumentation and load duplicating equipment; and heating, ventilating and lighting equipment as necessary. Each prototype unit will establish data which will be used to gain an understanding of residential energy use.

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ENERGY LABORATORY

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JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Task Order 37 and Follow On.

CONTRACT NUMBER: EX-76-A-01-2295

CONTRACTOR (NAME AND ADDRESS):

Massachusetts Institute of Technology
Energy Laboratory - E38-472
Cambridge, MA 02139

TELEPHONE: (617) 253-3408

PRINCIPAL INVESTIGATOR: R.D.Tabors (P. Powell)

DIRECTING ORGANIZATION AND ADDRESS:

Department of Energy
PV Energy Systems Division
600 E Street, N.W.
Washington, D.C. 20585

TELEPHONE: (202) 376-1956

PROJECT ENGINEER: Andrew D. Krantz

CURRENT CONTRACT PERIOD:

FROM: June 1, 1980 **TO:** September 30, 1980

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:

CONTRACT FUNDING:

FY	$	SOURCE:
80	240,000.	DOE

SUMMARY:

This work is a continuation of efforts undertaken by the MIT Energy Laboratory to develop, implement and interpret a set of policy analysis tools for the market development of the photovoltaic technology. This effort has focused in three basic analysis areas: Utility Worth Analysis; Market Analysis; and Legislative Analysis.

BEST DOCUMENT AVAILABLE

September 1980

JPL-PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Task Order 37 and Follow On

CONTRACT NUMBER: EX-76- A-01-2295

CONTRACTOR (NAME AND ADDRESS): Massachusetts Institute of Technology Energy Laboratory - E38-472 Cambridge, MA 02139 TELEPHONE: (617) 253-3408 PRINCIPAL INVESTIGATOR: R.D.Tabors (P.Powell)	DIRECTING ORGANIZATION AND ADDRESS: Department of Energy PV Energy Systems Division 600 E Street, N.W. Washington, D.C. 20585 TELEPHONE: (202) 376-1956 PROJECT ENGINEER: Andrew D. Krantz

CURRENT CONTRACT PERIOD:

FROM: October 1, 1980 TO: September 30, 1981

PROBABLE PROJECT COMPLETION DATE:

AREA/TASK:

CONTRACT FUNDING:		SOURCE:
FY 81	$ 800,000.	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The objective of the MIT Energy Laboratory photovoltaic project for the FY 81 period is to continue to develop and apply the analytic tools required to evaluate the future functioning of the market (both supply and demand) for photovoltaic power systems. To achieve this objective requires the development of analytic tools covering a breadth of market-related areas that include financial, economic and institutional analyses as well as studies of basic market structure and its regulation. Past, present and future work of the MIT/EL reflects the requirement of the photovoltaic program to understand the function of the economic, behavioral and regulatory environment into which photovoltaic systems will be introduced in increasing numbers.

September 1980

NASA/LEWIS RESEARCH CENTER

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: PV Balance-of-System Cost Estimates

CONTRACT NUMBER: NASA C-42701-D, Task PV-5

CONTRACTOR (NAME AND ADDRESS):
The Aerospace Corporation
P. O. Box 92957
Los Angeles, CA 90009

TELEPHONE: 213/648-7126

PRINCIPAL INVESTIGATOR: Barry Siegel

DIRECTING ORGANIZATION AND ADDRESS:
NASA Lewis Research Center
21000 Brookpard Rd.
Cleveland, OH 44135

TELEPHONE: 216/433-4000, ext. 5255

PROJECT ENGINEER: William Brainard

CURRENT CONTRACT PERIOD:

FROM: Sept. 9, 1980 **TO:** Jan. 15, 1981

PROBABLE PROJECT COMPLETION DATE: Jan. 15, 1981

AREA/TASK: Test & Applications

CONTRACT FUNDING:

FY	$	SOURCE:
80	30,240	DOE

SUMMARY:

Estimate the costs for the balance-of-system components for stand-alone PV systems in sizes up to 10 kWp. These terrestrial systems will include controls, storage and regulation, but not DC to AC converters. Prices will be estimated for 1982, 1986, and 1990, all in 1980 dollars. The impact of quantity purchases of PV systems will be assessed.

For the 1990 systems, alternate price estimates will be presented for improved technology components, including energy storage systems. Use as the initial data base the cost data at LeRC for those systems built and installed by LeRC.

10-01-80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Service, Labor and Materials for Inspection, Assembly, Testing of PV Modules and Panels

CONTRACT NUMBER: DEN 3-5

CONTRACTOR (NAME AND ADDRESS):
DIKU Tool and Die, Inc.
8141 Tyler Blvd.
P. O. Box 435
Mentor, OH 44060

TELEPHONE: 216/951-9660

PRINCIPAL INVESTIGATOR: Steve Kaiser

DIRECTING ORGANIZATION AND ADDRESS:
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

TELEPHONE: 216/433-4000, ext. 6635

PROJECT ENGINEER: John Toma

CURRENT CONTRACT PERIOD:

FROM: Sept. 22, 1977 **TO:** Indefinite

PROBABLE PROJECT COMPLETION DATE: Indefinite

AREA/TASK: Test and Applications

CONTRACT FUNDING:		SOURCE:
FY 77	$ 36,054	DOE
FY 78	$ 75,752	DOE
FY	$	
FY	$	
FY	$	

SUMMARY:

Provide supporting services to Lewis Research Center for PV module inspection and testing, panel assembly and testing, packaging and shipping.

10-01-80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Market Assessment of PV Energy Systems for Agricultural Applications in Developing Countries

CONTRACT NUMBER: DEN 3-180

CONTRACTOR (NAME AND ADDRESS):
Donovan, Hamester & Rattien, Inc.
1055 Thomas Jefferson St., N.W.
Washington, DC 20007

TELEPHONE: 202/342-5400
PRINCIPAL INVESTIGATOR: Dr. Anil Cabraal

DIRECTING ORGANIZATION AND ADDRESS:
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135

TELEPHONE: 216/433-4000, ext. 5255
PROJECT ENGINEER: Donald Bogart

CURRENT CONTRACT PERIOD:
FROM: 11-14-79 **TO:** 7-31-81

PROBABLE PROJECT COMPLETION DATE: 7-31-80

AREA/TASK: Test and Applications

CONTRACT FUNDING:

FY	$	SOURCE:
80	294,000	DOE

SUMMARY:

The contract study is a two-phase assessment of mid-and long-range markets for U.S.-produced PV-power systems as applied to agriculture in small-scale, decentralized applications. Phase I evaluated over 150 countries and recommended 14 countries for more in-depth study.

The recommendations were based on a variety of criteria including extent of current and expected U.S. business involvement in the country, extent and diversity of the agricultural sector, and the country's interest in renewable energy technologies. The countries recommended were: Argentina, Brazil, Mexico, Peru, Greece, Spain, Morocco, Sudan, Cameroon, Kenya, Nigeria, Indonesia, Philippines, and Thailand.

Phase I of the study also includes detailed characterization of the agricultural sectors of the 14 countries as well as preliminary identification of prime photovoltaic applications in each of the countries. A wide variety of applications are being evaluated and include the following: irrigation, refrigeration, ventilation, grinding, drying and storage, livestock production, on-farm food and fiber processing.

Phase II in-country trips are in the planning stage with a pilot trip to the Philippines scheduled for November 1980 with the balance of the in-country visits to be completed in the first quarter of CY 81. The visits are primarily fact-finding missions aimed at gathering data to satisfy the objectives of this study. The data to be collected is multi-dimensional and will require interviews with a wide variety of people.

The final report of this study is planned for the third quarter of CY 81.

10-1-80

JPL

PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Modular Photovoltaic Stand-Alone Systems

CONTRACT NUMBER: DEN 3-207

CONTRACTOR (NAME AND ADDRESS):
Hughes Aircraft Company
P. O. Box 90515
Los Angeles, CA 90009

TELEPHONE: 213-670-1515 Ext 6864
PRINCIPAL INVESTIGATOR: George J. Naff

DIRECTING ORGANIZATION AND ADDRESS:
NASA - Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135

TELEPHONE: 216-433-4000 Ext 5255
PROJECT ENGINEER: Thomas M. Klucher

CURRENT CONTRACT PERIOD:
FROM: 11-24-80 **TO:** 11-24-82

PROBABLE PROJECT COMPLETION DATE: 11-24-82

AREA/TASK: Systems Development And Engineering

CONTRACT FUNDING:

FY	$	SOURCE:
79	290K	DOE
80	170K	DOE

SUMMARY:

There are two objectives for this contract. The primary objective is to develop a family of modular stand-alone power systems that cover the range in power level from 1KW to 15KW and is easily adaptable to different environments and applications, is reliable, and is low in cost. A secondary objective is to compile, evaluate, and determine the economic and technical status of available, and potentially available, technology options associated with the balance of stand-alone systems.

STATUS: Contract award on 11-24-80.

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Market Assessment of PV Enérgy Systems for Cottage Industry Applications in Developing Countries

CONTRACT NUMBER: DEN 3-197

CONTRACTOR (NAME AND ADDRESS):
IIT Research Institute
10 W. 35 Street
Chicago, IL 60616

TELEPHONE: 312/567-4000

PRINCIPAL INVESTIGATOR: Mr. Robert Lapen

DIRECTING ORGANIZATION AND ADDRESS:
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

TELEPHONE: 216/433-4000, ext. 5255

PROJECT ENGINEER: Donald Bogart

CURRENT CONTRACT PERIOD:

FROM: May 23, 1980 **TO:** July 31, 1981

PROBABLE PROJECT COMPLETION DATE: July 31, 1981

AREA/TASK: Test and Applications

CONTRACT FUNDING:

		SOURCE:
FY 80	$ 311,000	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

The contract study is a two-phase assessment of mid- and long-range markets for U.S.-produced PV-power systems as applied to cottage industries in small-scale, decentralized applications.

Phase I evaluated 150 countries and recommended 14 countries for more in-depth study. The recommendations were based on a variety of criteria including extent of current and expected U.S. business involvement in the country, extent and diversity of the cottage industries in the countries and the country's interest in renewable energy technologies. The countries recommended were: Argentina, Brazil, Mexico, Egypt, Morocco, Spain, Turkey, Cameroon, Kenya, Madagascar, India, Republic of Korea, Malaysia, Philippines.

Phase I of the study also includes detailed characterization of the cottage industry sectors of the 14 countries as well as preliminary identification of prime photovoltaic applications in each of the countries. A wide variety of applications are being evaluated and include the following: spinning and weaving, production of agricultural implement, electrical and mechanical workshops, tile and brick manufacture, leather-tanning, lumbering and sewing.

Phase II in-country visits are in the planning stage with a pilot trip to the Philippines scheduled for November 1980 with the balance of the in-country visits to be completed in the first quarter of CY 81. The visits are primarily fact-finding missions aimed at gathering data to satisfy the objectives of the study. The data to be collected is multi-dimensional and will require discussions and interviews with a wide variety of people.

The final report of this study is planned for the third quarter of CY 81.

10-1-80

JPL
PHOTOVOLTAICS TD&A LEAD CENTER

TITLE: Photovoltaic Stand-Alone Systems Design Handbook

CONTRACT NUMBER: DEN 3-195

CONTRACTOR (NAME AND ADDRESS):
Monegon, Ltd.
4 Professional Drive
Suite 130
Gaithersburg, MD 20760
TELEPHONE: 301/258-7540
PRINCIPAL INVESTIGATOR: Harold L. Macomber

DIRECTING ORGANIZATION AND ADDRESS:
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

TELEPHONE: 216/433-4000, ext. 5255
PROJECT ENGINEER: Thomas M. Klucher

CURRENT CONTRACT PERIOD:
FROM: April 1980 **TO:** March 1981

PROBABLE PROJECT COMPLETION DATE: March 1981

AREA/TASK: Systems Development & Engineering

CONTRACT FUNDING:		SOURCE:
FY 79	$ 60,000	DOE
FY	$	
FY	$	
FY	$	
FY	$	

SUMMARY:

Objective of the contract is to develop a concise, self-contained photovoltaic design handbook for stand-alone systems. The "handbook" shall be educational in nature, suitable for use by applications engineers inexperienced with photovoltaic systems, and shall contain sufficient design and application information to enable users to easily establish initial sizing, configurations and design approaches in order to evaluate photovoltaic systems.

A draft brief of the handbook has been received from the contractor and approved by LeRC. A full handbook draft is due in early October 1980 with the final camera-ready copy due March 1981.

10-1-80

TITLE: International Village Power Market Study

CONTRACT NUMBER: DEN 3-49

CONTRACTOR (NAME AND ADDRESS):
Motorola Semiconductor
5005 E. McDowell Road
Phoenix, AZ 85008

TELEPHONE: 602/244-8900

PRINCIPAL INVESTIGATOR: Clyde Ragsdale

DIRECTING ORGANIZATION AND ADDRESS:
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

TELEPHONE: 216/433-4000, ext. 5255

PROJECT ENGINEER: Donald Bogart

CURRENT CONTRACT PERIOD:
FROM: Dec. 17, 1989 **TO:** March 19, 1980

PROBABLE PROJECT COMPLETION DATE: Nov. 30, 1980

AREA/TASK: Test and Applications

CONTRACT FUNDING:

FY	$	SOURCE
79	78,400	NASA
80	900	NASA

SUMMARY:

The contractor shall identify the opportunities for small (<10 kW$_p$) dispersed, photovoltaic (PV) systems to meet the needs of remote or isolated communities in developing countries. Contractor will conduct interviews with appropriate individuals in the potential market sector such as manufacturers, distributors, government embassies, international agencies and financial institutions, etc. Contractor will visit selected foreign countries to establish a market data base which includes, as a minimum, the following information: resource requirements, existing application power sources, range of power requirements and energy costs, substitute products, volume projections, market size, location, market potential and possible participants for cooperative projects.

The contractor has completed all activity with the exception of the preparation of the final report. A draft has been received and reviewed by LeRC and returned to the contractor. The final report is expected at the end of November 1980.

PART THREE
BIBLIOGRAPHY

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Chamberlain, R.G., Aster R.W. and Firnett, P.J., SAMICS Cost Account Catalog Version 4, Report No. 5101-154, Jet Propulsion Laboratory, Pasadena, California, April 21, 1980.

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Chen, C.P., Fracture Strength of Silicon Solar Cells, Report No. DOE/JPL-1012-32, 5101-137 and JPL Publication 79-102, Jet Propulsion Laboratory, Pasadena, California, October 15, 1979.

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Low Cost Silicon Solar Array Project (LSSA) Project Quarterly Report - 3 for the Period October 1976-December 1976, Report No. ERDA/JPL-1012-77/2 and 5101-24, Jet Propulsion Laboratory, Pasadena, California, August 15, 1977.

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Zunger, A., Contemporary Pseudopotentials-Simple Reliability Criteria, SERI/TP 32-288, Energy Research Institute, Golden, Colorado.

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